Energy and Environmental Implications of Differential Household Consumption Pattern: An Analysis Across Settlement Categories Within Input-Output Framework

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SWARUP SANTRA

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NEW DELHI – 110067

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JAWAHARLAL NEHRU UNIVERSITY

Centre for the Study of Regional Development

School of Social Science

New Delhi – 110067

Date: 28.06.2021

DECLARATION

I, **SWARUP SANTRA**, do hereby declare that the thesis titled "**ENERGY AND ENVIRONMENTAL IMPLICATIONS OF DIFFERENTIAL HOUSEHOLD CONSUMPTION PATTERN: AN ANALYSIS ACROSS SETTLEMENT CATEGORIES WITHIN INPUT-OUTPUT FRAMEWORK**" submitted by me is a bona fide work for the degree **DOCTOR of PHILOSOPHY** and it has not been submitted to any other university for the award of any other degree.

Swarup Santra

(SWARUP SANTRA)

JAWAHARLAL NEHRU UNIVERSITY

Centre for the Study of Regional Development

School of Social Science

New Delhi – 110067

CERTIFICATE

This is to certify that the thesis titled **"ENERGY AND ENVIRONMENTAL IMPLICATIONS OF DIFFERENTIAL HOUSEHOLD CONSUMPTION PATTERN: AN ANALYSIS ACROSS SETTLEMENT CATEGORIES WITHIN INPUT-OUTPUT FRAMEWORK"** submitted by **Mr. SWARUP SANTRA** in partial fulfillment of the requirements for award of the degree **DOCTOR of PHILOSOPHY (Ph.D.) of Jawaharlal Nehru University**, New Delhi, has not been previously submitted in part or in full for any other degree of this university or any other university / institution.

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Signature of the Supervisor

(DR. ELUMALAI KANNAN)

Date: 22/06/2021

Signature of the Chairperson

(PROF. MILAP PUNIA)

Date: 23.6.2021

Chairperson
Centre for the Study of Reg. Dev.
School of Social Sciences
Jawaharlal Nehru University
New Delhi - 110067

Dedicated to

My Parents:

Mr. Mansha Santra

&

Mrs. Chhabi Santra

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ANOVA	Analysis of Variance
BEE	Bureau of Energy Efficiency
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CI	CO2 Emission Intensity
cMDS	Classical Multi-Dimensional Scaling
CO2	Carbon Dioxide
COP	Conference of the Parties
CPE	Consumption Pattern Effects
CSO	Central Statistical Organisation
EFs	Emission Factors
EI	Energy Intensity
EIO	Energy Input-Output
EIOA	Energy Input-Output Analysis
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GOI	Government of India
HIC	Higher Income Class
IDA	Index Decomposition Analysis
IEA	International Energy Agency
INC	Inter-governmental Negotiation Committee
INCCA	Indian Network for Climate Change Assessment
IOTTs	Input-Output Transaction Tables
IPCC	Inter-governmental Panel on Climate Change
Kg	Kilogram
LIC	Lower Income Class
LMDI	Logarithmic Mean Divisia Index
LPG	Liquefied Petroleum Gas
MDGs	Millennium Development Goals
MDS	Multi-Dimensional Scaling
MIC	Middle Income Class

MJ	Million Joule / Mega Joule
MPCCE	Monthly Per Capita Consumption Expenditure
NAPCC	National Action Plan for Climate Change
NCV	Net Calorific Value
NOx	Nitrogen Oxides
NSS	National Sample Survey
NSSO	National Sample Survey Organization
OECD	The Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
SCP	Sustainable Consumption and Production
SDA	Structural Decomposition Analysis
SDGs	Sustainable Development Goals
SO2	Sulfur Dioxide
TERI	The Energy and Resources Institute
TPEI	total primary energy intensity
UNCED	UN Conference on Environment and Development
UNDP	The United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
WMO	World Meteorological Organization
WPI	Wholesale Price Index
WSSD	World Summit on Sustainable Development

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Chapter - 1

Introduction

1.1. Economic Development and Climate Change

Climate change has become a major challenge that the human beings face in the contemporary world. The climate change has immense implications for protecting and maintaining the environmental balance[1] taking all aspects of the environment into its consideration. It can affect the production of food, fresh water supply and can damage our health systems unbearably (Butnar and Llop, 2011). Overall, it has the potential to damage natural ecosystems[2]. It is a well-accepted among the development thinkers that climate change affects the poor people badly, and the developing countries are in the most vulnerable situation to face climate change (Islam and Winkel, 2017). The developing

[1] Environmental balance is the balance among the different components of ecosystems (Cassman and Harwood, 1995).

[2] Ecosystems can be defined as a dynamic complex entity comprising of animals, plants, microorganisms and nonliving environment which are interacting continuously as a functional unit (Rebele, 1994).

countries are less equipped in responding to climate change – they are less resourceful to win the battle against climate change. The vulnerability[3] to climate change is closely related to poverty.

Climate change is considered as the side-effect of the rapid economic process. The industrial revolution[4] has accelerated the process of climate change. It is the outcome of greedy economic development. Ever since the industrial revolution emerged in Europe and spread to rest of the world, the economic activities have started over-riding the nature and led to irreparable change in the climate, during the past two centuries and it is resulting in 'the rising concentrations of greenhouse gases (GHGs) in the earth's atmosphere' (GOI, 2003).

Human activities have contributed towards the increase of atmospheric concentration of GHGs[5] for over the last century and this has led to the enhancement of the natural greenhouse effect[6]. Global warming and climate change threaten the future development process of humans as well as the whole ecosystem. The concept of sustainable development comes here; handling climate change issues have become an integral part of the global challenges facing for maintaining sustainable development.

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[3]Vulnerability "is a measure of a person or group's exposure to the effects of a natural hazard, including the degree to which they can recover from the impact of that event" (Blaikie et al., 1994). The vulnerability of a region depends mostly on the wealth of that region. And the extent of poverty of any region limits its adaptive capabilities to respond to climate change.

[4] Industrial revolution is the process of transition of new manufacturing processes in Europe during the period of 1760 to 1840. Uses of steam power and new machines are the major features in it (Mohajan, 2019).

[5] Six Gases viz. *Carbon Dioxide* (CO_2)*, Methane* (CH_4)*, Nitrous Oxide* (N_2O)*, Per fluorocarbons (PFCs), Hydro fluorocarbons (HFCs), and SulphurHexafluride* (SF_6) accountable for a rise in the atmospheric temperature known as *Global Warming* and greenhouse effect, are called as Greenhouse Gases (Gielen and Kram, 1998).

[6] The greenhouse effect is a process that happens when gases in atmosphere trap the heat. This makes earth warmer and comfortable place to live (Kweku et al., 2017).

The people are taking different natural resources as basic sources of energy for their livelihoods; the uncontrolled uses of fossil fuels as energy sources created the problem of climate change. However, the problem of climate change has been considered as the long-run issue by the policymakers. In short-run, they are much more concerned about other critical sustainable development issues that are important to the human for their immediate survival.

However, even in the short term, climate change started affecting human welfare. It's not a mere long-run issue anymore. For example, agriculture is highly dependent on climatic conditions. According to Yuksel (2008), the existing level of climate variability creates significant risks for agriculture, and hence the economic infrastructure. Such a climatic threat must be addressed in a better way to address the long run aspects of regional climates.

In the United Nations' Millennium Development Goals (MDGs), and then in Sustainable Development Goals (SDGs), affordable energy accessibility is considered as among the crucial elements of economic progress (Setyowati, 2021). Energy affordability is also an essential part of poverty eradication. "Convenient, affordable energy is also important for improving health and education, and for reducing the human labour required to cook and meet other basic needs" (Yuksel et al., 2013).

The increasing level of CO_2 and other GHGs are mainly caused by the combustion of fossil fuels. and other human actions. A country's ability to achieve the sustainable development goals is highly influenced by the impact of climate change, associated public policies and its overall socio-economic progress. The journey to the sustainable development goals affects, in turn, the prospects of formulating climate change mitigation policies. The GHGs emission will be strongly affected by the different characteristics, such as the technological and socio-economic dimensions of the various development paths. Therefore, these characteristics will also affect the rate, scale and impacts of climate change, and the ability to adapt[7] and to mitigate[8] (Sathaye, et al, 2006).

1.2. Climate Change and GHGs Emission in India

There are many reasons for India to be worried about the impact of climate change (NAPCC[9], 2008; INCCA[10], 2010). The Indian subcontinent is the most vulnerable area to be affected highly by the climate change in future. Indian economy is highly dependent on agriculture and forestry with more than 50 per cent of its workforce is still employed in these sectors, which are very highly climate-sensitive (BLS, 2010). That's the reason India is highly vulnerable to the climate change. Moreover, India has low financial adaptive capacity (Shukla et al., 2002) to fight against climate change.

Climate change affects the temperature, rainfalls, and causes immense flood and dryness unpredictably and frequently. These result in crop failures (Ali et al, 2017). Therefore, the risk is attached to half of India's population who are engaged in agricultural activities and they are poor as well. Any kind of crop failure and health hazards due to climate change will affect the poor people most (Akpinar-Ferrand and Singh, 2010). The rise of sea level is also alarming to India. Submerging the coastal and low sea level area would threaten and displace that vulnerable poor population from their

[7] Climate change adaptation is the process of adjusting to current and future climate change and its effects (Berkhout et al., 2006).

[8] Climate change mitigation is the efforts to bring down the GHGs emissions by using new technologies, renewable sources of energy and consumer behaviour, etc. (Metz et al., 2007).

[9] NAPCC stands for National Action Plan for Climate Change. It was launched in 2008 by the Government of India as an initiative to fight against climate change. There are total eight missions under it.

[10] INCCA stands for the Indian Network for Climate Change Assessment. INCCA was launched in 2009 by the initiatives of the Climate change division of Ministry of Environment, Government of India.

places. Besides, extreme weather events are creating a threat to water availability, food security, and overall human health (Cruz et al., 2007). Apart from the Indian low sea level area, almost 16 per cent of total land is drought-prone and about 12 per cent is flood-prone (CWC, 2011).

It would be beneficial to have an evaluation regarding the nature of GHGs emissions and its composition which causes climate change. In fact, India is the sixth-largest emitter of carbon dioxide (CO_2) in the world. According to UNEP (2002), India had emitted about 908 million tonnes of CO_2, which was about 4 per cent of the total CO_2 emission in the world – less than the USA's figure which was greater than 27 per cent of total global-historic emission, in 1998.[11]

However, India's position was much below based on per capita emission. It was about 0.93 million tons per capita per year – was much lower than the global average of 3.87 million tons per capita per year. In 2009, per capita CO_2 emission was about 1 ton, still much less than the average of the USA's 17 tons. India has about 4.6 per cent annual growth of GHG emissions, compared to the 2 per cent of global average in 1998. However, India has tripled annual emissions from less than 600 metric tons to 1600 metric tons between 1990 and 2009 (IEA, 2011).

The two most important policies had been launched by the government of India, so far, are National Electricity Policy and *Pradhan Matri Ujjala Yojana*. The national electricity policy was adopted in 2005 and in the next year, the National Rural electrification policy had been adopted. The objectives of these two policies are to reach every household in India with an electricity connection. A similar policy for LPG is

[11] The historic emission is a stock concept. This denotes the estimate of cumulative emissions from known historical period (Moran et al., 2014).

Pradhan Mantri Ujjala Yojana, launched in 2016. Although the basic target of these two energy sources is the households, the household consumption pattern was not the issue here. The issue of accessibility of electricity and LPG mainly in the rural area is the basic cause for not availing these. However, *Pradhan Matri Ujjala Yojana* tried to find the targeted household, providing many incentives to BPL families to avail of the LPG cylinder. Another important energy policy in India is labeling electrical appliances according to their energy efficiency with different starts. The Bureau of energy efficiency (BEE) had to play a crucial role, here.

1.3. Global Consensus on Climate Change

With the increase in evidence from the scientific investigation of anthropic interference on the climate system, public awareness across the globe on environmental issues at the global level started pushing the issues of climate change into the global politics by the mid of 1980s (Butnar and Llop, 2011; Chang and Lin, 1998). In 1988, the UN General Assembly, for the first time, incorporated the climate change issues on the request from the Government of Malta, and a resolution was adopted on the “Protection of global climate for present and future generations of mankind” (GOI, 2003). The global consciousness on climate change have been brought together the global community came to one platform and took initial steps in 1992 (United Nations Framework Convention on Climate Change, UNFCCC) and subsequently in different meets.

The researchers tried to focus the researches on defining and formulating effective methods and policies to cut down the environmental loads which had been caused by the increasing human activities of production and consumption (Liu et al., 2009). The new researches had started providing not only the information regarding the negative impacts of climate change but the knowledge about the remedial policy issues to reduce such environmental loads **(**Butnar and Llop, 2011).

It is in 1997 in Kyoto, Japan; the global community met again (*Kyoto Protocol*) to curb global greenhouse gas emissions and started signing in the Kyoto Protocol. However, only a handful of countries had made some genuine efforts to reduce the emission level (Gupta, 2003). Most of the economies keep continuing their increasing emission along with the growth of the economy (Lagos et al., 2009).

The World Meteorological Organization (WMO) had set up the "*Inter-Governmental Panel on Climate Change* (IPCC)" in 1988 to assess the scientific information on climate change for the needs of the policymakers. And in 1990, the First Assessment Report was published by IPCC and it confirmed that climate change was a threat to human beings and it is urgent to call for a global consensus to combat that problem (IPCC, 2007). In the same year, the Second World Climate Conference at Geneva made a Ministerial Declaration addressing the climate issue, and UN General Assembly also responded to those calls by launching a platform for negotiation on climate change by an Inter-governmental Negotiation Committee (INC).

In 1992, in INC's fifth session, the governments adopted the United Nations Framework Convention on Climate Change (UNFCCC). At the UN Conference on Environment and Development (UNCED), the so-called "Earth Summit", in Rio-de-Janeiro, Brazil, and the Convention was opened for signature in 1992; and it came into force on 21st March 1994. And till 2002, almost 186 governments had signed for the Convention. After the Convention was signed, the governments met in the "Conference of the Parties" (COP) every year and in its third round of COP, the "Kyoto Protocol" was adopted in 1997 to negotiate the commitments from industrialized countries to combat climate change problem (GOI, 2003).

1.4. Agenda 21 and Sustainable Consumption

In the Rio Summit of the UNCED in 1992, the concept of 'sustainable consumption' got its importance for the first time in any international platform (Banbury et al., 2012; Kletzan et al., 2006). It is an accepted fact that the unsustainable patterns of production and consumption mainly in industrial countries are the major causes of environmental degradation globally (Akenji, 2014; Alfredsson, 2004). There were *27 principles* declared at that summit. One of the 27 principles is called "Reduction of Unsustainable Patterns of Production and Consumption" (Banbury et al., 2012).

The main policy document of that Summit was the *'Agenda 21'* and Chapter 4 of the Agenda was fully devoted to 'Changing Consumption Pattern' (Akenji, 2014). According to Agenda 21, wealth and prosperity improve the standard of living. However, that improvement of the standard of living must be through the change in lifestyles of the people (Hubacek et al., 2007). That changed in the lifestyle of the people must come through the change in consumption patterns towards more sustainable consumption (Banbury et al., 2012).

The consumption pattern must be "less dependent on the Earth's finite resources and more in harmony with the Earth's carrying capacity." And it was urged to all the nations to "examine, question and revise consumption patterns and behaviours" (Banbury et al., 2012). The poverty eradicating strategies by the nations and other socio-economic development programs should depend on the basic changes in production patterns and consumption patterns at the global level (Clark, 2007).

Therefore, Chapter 4 of Agenda 21 came out with two broad objectives to guide government actions: a) to promote the pattern of production and consumption which reduced the environmental negative impact and also to have the essential human requirements, and b) to build consensus about the impact of consumption and to find the way to bring the consumption patterns which is more sustainable (Akenji, 2014).

After twenty years of Agenda 21, the Division of Sustainable Development of the United Nations has had an assessment on the execution of “Agenda 21”, in 2012. The increasing consumerism at global level and increasing consumer class made thing difficult; the increase in consumption level over-exceeds the energy efficiency measures taken in different policies. This review report also says on the increasing environmental impact on the ecology. The global ecological footprint became more than the average bio-capacity in the world. The report provides the instruments for promoting sustainable production and consumption. Among them, the standards and labels, regulation on energy efficiency equipment, and resource use efficiency are important policy instruments. The report tried to focus on basic challenges the global economy facing. The global economy is gaining some efficiency in resource and energy use, however, this gain is overturn by the rapidly increasing consumption level globally. There is need for study the consumption patterns to reduce the overall consumption load or unsustainable consumption.

1.5. Adaptation and Mitigation of Climate Change

Adaptation is required to deal with climate change vulnerability and variability in forest ecosystems, coastal ecosystems, infrastructure, human health, and food security (Akpinar-Ferrand and Singh, 2010). The IPCC (2007) provided sectoral measures of adaption for different sectors. The inadequate resources, lower technological and infrastructure development, unskilled labour force, inefficient and unstable institutions left a country less equipped to fight against climate change. The Clean Development Mechanism (CDM) is being extensively discussed in case of reducing GHGs as the Kyoto Protocol comes to pass (Gupta, 2003). The CDM is a project-based mechanism based on climate change mitigation[12].

Climate change adaptation is the set of policies taken to lessen the climate change impact on the human being. It is a response to the climate change to reduce the vulnerability of human beings exposed in front of climate change. These are the policies to offset the effects of global warming. Climate change adaptation is the surviving effort that is tightly linked to the social and economic development of human beings (IPCC, 2007).

Unlike adaptation policies, the climate change mitigation is a preventive measure. Mitigating the climate change is to reduce GHGs emissions so that the intensity of climate change and global warming come down. Some examples of the mitigation are making energy-efficient buildings, adopting renewable energy sources, more sustainable transport systems, building sustainable and smart cities, promoting sustainable use of land and forest, etc. The adaptation of global warming is necessary, but mitigating the emission of greenhouse gases is also important.

Prevention is always better than protection. Without any mitigation efforts to reduce greenhouse gases, the works of adaptation to reduce the impact of global warming would be difficult to tackle after a certain limit. However, there is an economic and political challenge to mitigate global warming on a global scale. There is still an existing debate on economic underdevelopment and climate change. The people of developing

[12] Mitigation is the set of actions through which the intensity of radioactive forcing is to be decreased to lessen the possible impact of global warming. The climate change mitigation is not same as the climate change adaptation to global warming – adaptation is basically the action to tolerate the effects of global warming (Metz et al., 2007).

countries living under poverty, malnutrition, and food insecurity are seeking rapid economic development avoiding the environmental challenges associated with it. On the other hand, developed countries are also feeling reluctant to mitigate the emission as they are conscious about reducing economic activity.

The adaptation and mitigation are not policy substitutes; rather they are largely complementary. Though the adaptation is manageable in the short-run, for long-run sustainable development, mitigation is essential. Finding remedies for the root cause of the climate change problem would be a final path to restore environmental balance.

1.6. Demand-side Management of Climate Change

The global agreement at the World Summit on Sustainable Development (WSSD) in Johannesburg in 2002 said that the changing “unsustainable productions and consumption patterns” are the most important objective and essential requirements for sustainable development (Banbury et al., 2012). The role of sustainable production and consumption had been recognized in that World Summit to achieve sustainable development (Akenji, 2014). The WSSD had identified several tools and actions in a ten-year framework for sustainable production and consumption (Clark, 2007) to be implemented at global as well as local levels. The poverty eradication and the issues of sustainable production and consumption had been linked in WSSD.

It was recognized that the increasing consumption is no more restricted in developed countries; the consumption level of the emerging economies such as Brazil, China and India are also increasing rapidly. The emergence of the global consumer class is mainly due to the emergence of so-called ‘middle-class’ consumers in developing countries. India along with Brazil, China, and all industrialized countries had been identified as the target groups in WSSD to focus the sustainable production and consumption issues (Clark, 2007).

The governments committed to build respective national strategies, policies, and action plan to 'accelerate the shift' towards sustainable consumption and production (SCP). The market mechanism would be unable to attain the objective of sustainable consumption. Hence, there is a need for a government intervention. The generation of public awareness about the environmental and social problems associated with economic activities is also an important part. The concept of green consumerism should be encouraged among the citizens (Akenji, 2014).

This call was well accepted by the international policy community to take the path of sustainable consumption. However, various institutions have taken the multiple definitions of sustainable consumption, which resulted in no common agreement on the definition of sustainable consumption (Banbury et al., 2012). Gombert-Courvoisier et al. (2014) has tried to define sustainable consumption as a mode of consumption where individuals can fulfil their basic needs in short-run, while they still maintaining balance in socio-economic and ecological mechanisms in medium and long-run.

According to Manoochehri (2002), it is assumed that the path of sustainable consumption would significantly lower the usages of natural resources through individual choices, lifestyles, and behaviour. The behavioural change would influence the market mechanisms and it would lead to efficient utilization of resources (Abrahamse et al., 2007). Changes in consumption patterns through the influence of demand management in the classical economic model would change ultimately production patterns (Manoochehri, 2002; Jackson, 2004). However, there is a possibility of failure in connecting the elements of consumer behaviour and the elements of the sustainability agenda. Sometimes, the more pro-environment attitudes by mistake lead to more environmental pressure (Banbury et al., 2012).

1.7. Consumption Patterns of Households and Its Implications

Human acts on the environment while searching for their means of consumption. Humans have engaged themselves in different economic activities and exploited the environment for whatever they need by using, reusing, and throwing out the unusable materials back to the environment (Clark, 2007). The households are the basic unit of agents in case of consumptions. Households affect the environment through their everyday decisions on consumptions – what goods and services are needed to be purchased, in which way they would be used, etc. (Zacarias-Farah and Geyer-Allely, 2003). The other decisions like ‘where to live and to work, what kind of dwelling to have, how to manage their waste and where to go on vacation are also affecting the surrounding environments.

Any effort to reduce the environmental pressure, such as energy efficiency technologies, have been failed to draw desirable gains as it has been overweighed by the intensification of consumption of goods and services through increase in world population, and hence economic activity. The environmental impact of the consumption of goods and services by households is continuously increasing over the year. To decoupling the economic activity from the environmental pressure, the integrated policies combining the production system and the consumption patterns are required (Feng et al., 2010).

According to Brundtland (1987), in the report “Our Common Future”, the sustainable development is the progress in which the wants of current generation have been met without sacrificing the potentiality to meet the needs of the future generation. In this report, the term ‘sustainable consumption’ is conceptualized as the goods and services for basic needs and for better quality of life.

Sustainable consumption also includes the minimum use of natural resources and emitting less pollutants and waste so that the needs for future generation cannot be compromised (Feng et al., 2010). By sustainable consumption, one tries to reorient the consumption towards ‘environmental-friendly consumption behaviour’ and to reduce the environmental impact of the households (Abrahamse et al., 2007). A civilized society should try to regulate the household’s consumption towards a more sustainable one by linking sustainable consumption with specific targets to achieve sustainable development (Zacarias-Farah and Geyer-Allely, 2003).

Energy-related CO_2 emissions are still significantly higher than the required level to keep the Kyoto Protocol commitments. As there is increasing use of energy at the household level, therefore there is ample scope to reduce energy usage and the related CO_2 emission (Feng et al., 2010). For this purpose, household energy consumption is needed to be given more attention as it is given to the production systems for the last many decades (Girod and Haan, 2003).

The energy in households is an essential element in household consumption. The well-being of households depends on the level of energy consumption by households (Feng et al., 2010). Not only it works as an end-use, but it is used as an intermediate element also. The energy in households required for lighting, heating, and cooling. However, cooking is the most important part of the household course which consumes the largest portion of household energy, mainly in the developing country (Pachauri and Jiang, 2008).

In India, firewood and LPG are used for cooking purposes. Coal, dung cake, and sometimes kerosene is also used for cooking. On the other hand, electricity and kerosene are the two sources of energy for lighting. The rural households use the traditional sources of energy like firewood and dung cake, at a large scale, for cooking. These sources of energy are easily available in the rural area; and the modern sources like LPG either it is not easily accessible due to lack of sufficient infrastructure and proper distributional system in a rural area, or it is not readily affordable to the poor households (Pachauri and Jiang, 2008). On the other side, firewood is not available in urban areas, and cooking is mostly dependent on LPG; sometimes, electricity, kerosene, and coal are also used (Alam et al., 1998). The dependency on firewood is an indicator of the lack of accessibility and affordability of alternative and modern sources of energy to poor households in the rural area (Pachauri and Jiang, 2008).

The main sources of increasing energy demand in households, in any country, are demographic change and economic growth. As the members of the households (i.e., household size) increase the total energy consumption also rises, but the per capita energy consumption decreases due to the effect of scale economics. Using the same logic, it can be said that the division of the joint family into a nuclear family stimulates the rise of total energy requirements.

As the income of the household increases, given the household size, the affordability of the households also increases. The income effect pushes the households into the higher strata on the income ladder. Now they can able to purchase more goods and services including energy items. Therefore, the total energy consumption is supposed to increase in those households. At the same time, they may able to afford the more sophisticated sources of energy which are costly than the traditional ones (Jackson, 2004).

Along with the rise in income of the households, they would substitute those traditional sources to modern sources. These effects can be seen through the Engel curve analysis.

In this process, households may purchase less energy-intense (energy efficient) goods and services. However, less energy intensity can encourage households to consume additional goods and services which leads to additional consumption of total energy ultimately. This is known as rebound effects in energy economics. Along with these two factors, the improvement of the technological level helps to reduce household energy consumption (Zacarias-Farah and Geyer-Allely, 2003).

Households generally use energy which affects the environment through the combustion of fossil fuels at the household's level as direct energy. Apart from the direct consumption of energy, households also consume energy indirectly by consuming all varieties of goods and services. A certain amount of energy is necessary to produce any goods and services, directly and indirectly in production sectors.

Therefore, any item consumed by the households is containing a certain amount of energy embodied within it. Similarly, pollution is emitted while burning those sources of energy (Zacarias-Farah and Geyer-Allely, 2003). Hence, every household's goods and services are responsible for a certain amount of emission to the atmosphere. For example, thermal electricity is generated by combusting coal or oil, or gas, and in this process, it releases some pollution to the air. These energy-related emissions are responsible for environmental degradation (Clark, 2007).

The energy can be used as substitutes for labour; It can save time. The technological progress has reduced the labour hours, and improved the quality of life; the technology has transformed the lifestyles (Pachauri and Jiang, 2008). The improved standard of living has a two-way process; the developments in technology and change in lifestyle.

The standard of living has reached much ahead of just meeting the basic needs (Hubacek et al., 2007). The idea of the quality of life has become a matter of organizing our own time and lives, and this has to a large extent been achieved through an energy-intensive lifestyle (Anker-Nilssen, 2003).

Since the tastes and preferences of an individual conform to the socially determined structure, the consumption behaviours of any person create a roughly consistent consumption pattern (Roy and Pal, 2009). The lifestyle is defined here in a functional sense. The lifestyle is reflected through the correlation between the level and pattern of consumption, and socio-economic, demographic parameters. Age, household income, occupation, education and gender of the family members, family size, and ethnicity, etc. are some example of households' socio-economic, demographic parameters. High consumption is essential for maintaining the standard of living (Hubacek et al., 2007).

However, the structure of the consumption basket is also an important issue to be concerned by all the individuals of the society (Roy and Pal, 2009). The wealthy people purchase a proportionately larger amount of luxurious goods. And sometimes, the degree of the composition of luxurious goods in the total consumption basket determines the 'status symbol' by society. Individuals consume more goods to maintain their social position and status (Roy and Pal, 2009; Pachauri and Jiang, 2008).

Since the late 1980s, many energy researchers had started investigation of the influence of consumers' behavior on the energy use. They had introduced lifestyle as a determining factor for household energy consumption. Their major focus was the impact of lifestyle on the energy consumption and the environment (Adaman et al., 2011). Other researchers like Rees (1995), Daly (1996), and Duchin (1998) argued that "most environmental degradation can be traced to the behavior of consumers either directly, through activities like the disposal of garbage or the use of cars, or indirectly through the production activities undertaken to satisfy them". Lenzen (1998) had examined the effect of households' actions on energy consumption and GHGs emissions in Australia. Weber and Perrels (2000) had investigated the effects of lifestyle changes on energy requirements and emission in West Germany, France, and the Netherlands.

1.8. Aim of the Study

The policymakers are concerned about the environmental issues and they tend to consider these issues while framing a public policy for the environment. The foremost policies for environment was for mainly the eco-efficient technological progress, while allowing the consumption to grow freely. The final consumption is the ultimate motives for production of all goods and services. That's the reason, the consumption is called to be a "driving force" for the environmental load (Aalbers et al., 2007). Apart from the technological progress and consumption level, the environmental load is also dependent on the structure of consumption basket. The composition of different goods defines the structure of the consumption basket. The composition of consumption forms the consumption patterns.

By changing the consumption patterns, it is possible to reduce the environmental load caused by consumption (Vringer et al., 2010). The 12th Five Year Plan discussed about having balanced urbanization in India (Alam et al., 1998). And an investigation of the consumption structure and lifestyle in this regard can make a significant influence on policymaking to reduce the environmental loads (Jackson, 2004; Hubacek et al., 2007). Whether promoting small towns would give us more balanced urban areas or not – purely based on the consumption structure – that is an important area of research for urban as well as environment planners. This study aims to analyze different expenditure classes in different settlement categories in India. The comparison of the consumption structure and the energy requirement and its environmental load, in the form of emission, for the same expenditure groups in different settlement categories can give vivid pictures of environmental responsibility for different consumption patterns.

1.9. Justification for the Study

There is a need for reduced energy consumption and related environmental loads for India. And there are multiple reasons behind the necessity of the study on household consumption patterns. Household sector is the major consumers of a country's total energy use. About 40 per cent of total direct commercial and non-commercial energy is consumed by the households in India (Pachauri and Spreng, 2002).

Traditionally, the policy makers analyse the energy use and CO_2 emission through the sector-based approaches. In a sector-based approach, the analysis has been done for only a sector like industrial, transportation, commercial, and residential. Among them, only the residential sector has the direct interaction with the final consumers. Through the different end-use of energy such as cooking, lighting, appliances, water and room heating, etc., the consumers directly use the energy sources, in residential sector (Bin and Dowlatabadi, 2005). There are so many socio-economic, cultural, demographic, geographic, environmental factors that affect household behaviour on the choice of a particular commodity among the others. And in such a way, the demand for household energy is also influenced by these factors. So, the success of any supply-side scheme also depends on the factors of the demand-side mechanism.

1.10. Objectives of the Study

From the above discussion of review of literature and scope of the study, the present study focuses on the following objectives.

1. To analyse the consumption patterns of the households of different income classes across different size settlement categories over the period 1993-94 to 2011-12 in India.
2. To estimate the direct energy requirement and related CO_2 emissions at household level by different income classes across settlement categories over the same study period.
3. To compute the total energy requirement, direct and indirect at household level by different income classes across different settlement categories.
4. To analyse the energy-related total CO_2 emission, directly and indirectly, at household level by different income classes across different settlement categories.
5. To analyse the effects of household consumption patterns on the energy-related CO_2 emissions at household level by different income classes across different settlement categories over the period, 1993-94 to 2011-12.

1.11. Hypotheses

i. There are no significant differences of consumption patterns at households of different income classes across different settlement categories.

ii. The households of higher income classes and of cities consume more direct energy and emit more direct energy-related CO_2 on per capita basis than households of lower income classes and of rural area.

iii. The higher income households in city consume more total energy, directly and indirectly, on per capita basis than lower income households in rural area.

iv. The higher income households in city emit more energy-related CO_2, directly and indirectly than lower income households in rural area.

v. The differential household consumption patterns have no effects on CO_2 emission in India.

1.12. Chapter Outline of the Thesis

The present thesis contains seven chapters. The first chapter provides introduction and background of the topic. This chapter discusses the problems of climate change and its association with the consumption patterns. The aims and the objectives of the thesis are provided. The *second chapter* is on differential household consumption patterns. Having the analysed different consumption patterns among the households, this chapter identifies the groups or clusters of households with almost similar types of consumption patterns. The rest of the analysis in this thesis would rely on the classification of the households into the different clusters of households with differential consumption patterns.

Chapter 3 attempts to get the energy intensity (energy embodied-ness) and related CO_2 emission intensity of the production sectors of the economy through applying the energy input-output analysis. *Chapter 4 discusses* the direct energy requirements and related CO_2 emissions. The sources of energy directly consumed in households are considered here. However, as the households use much more energy by consuming the non-energy items (the energy embodied), so mere analysis of the direct energy usage does not provide the complete picture of the story. Detailed analysis of energy used indirectly and related CO_2 emission is required. The *fifth chapter* estimates the total energy requirement, direct and indirect taken together, and the related CO_2 emission (direct plus indirect). The *sixth chapter* discusses consumption pattern effects on CO_2 emissions. Through this analysis, the partial effects of consumption patterns on CO_2 have been calculated and separated from the other factors through structural decomposition analysis. And the final chapter, *seventh chapter* provides the summery of findings and some concluding remarks. An overview of the study has been added. It also provides policy recommendations based on the findings of the study.

Chapter – 2

Household Consumption Patterns

2.1. Background

Consumption is the ultimate goal of any economic activity. However, in a capitalist mode of society, the 'unlimited wants' of the people had led to unnecessary consumption and unsustainable consumption (Tu et al., 2013). The consumption is not only receiving the output from the production sectors, but it is enhancing further production by creating the demand for the output. In another word, 'the consumption is not only the end but also the start of production'. The consumption also influences the exchange and distributional patterns in society (Clark, 2007). Therefore, it can be said that the consumption has a critical position and a crucial role in shaping economic activities.

Sustainable consumption has drawn much attention from researchers in recent times – in academics as well as in policy-making (Kletzan et al., 2006). It is almost accepted now by the policymakers across the world that sustainable consumption is the core element of sustainable economies. It is not just the sustainable industrial production process, the sustainable consumption along with the sustainable production makes together the sustainable economies. Traditionally, most of the environmental issues were solved through changes in the production process only. And that processes were merely linked with the final consumers (Clark, 2007). Any environmental strategy which is dealing the production sectors definitely reduced the environmental loads through the new design, new products, sues of different raw materials, etc. (Tu et al., 2013). However, the issues of selection, use, re-use, and disposal of the products by the final consumers cannot be dealt by the production-oriented strategies.

Many policies have been taken through more efficient and cleaner production processes to get a better environment. However, the changing consumption patterns towards an unsustainable manner are offsetting the environmental gain achieved through the clean production processes (Clark, 2007). The consumption pattern gets shaped and influenced by the population growth, better-quality standard of living, and a person's wishes for more consumption. As there is an improvement in environmental compatibility in the production process on the supply side, the people are getting chances to consume more of those environmentally efficient goods and services (Tu et al., 2013).

This 'rebound effects'[13] is reducing the benefit obtained in the production process by adopting environmentally efficient process (Clark, 2007). The sustainable consumption can guarantee the benefit of sustainable production. The sustainable production and sustainable consumption are complementary to each other to build

[13] Rebound effect states that any technological progress can lower the price of the goods, and ultimately due to decrease in price level the consumption level may increase. In many cases, it has been seen that any technological advancement may reduce energy intensity in one hand, but the energy consumption may increase, on other hand due to decrease in price (Brannlund et al., 2007).

sustainable economies. Sustainable production would produce goods and services through the environmentally efficient production processes which are ‘non-polluting, conserving the resources and energy, economically viable and safe for the workers and consumers’. The sustainable consumption includes many aspects of our life. It includes the consumption of goods and services which are essential to meet the basic needs and also to improve the standard of living. On the other side, it also includes the minimum use of natural resources and pollution is as minimum as possible (Kletzan, et al., 2006).

2.2. Household Consumption Patterns

Household consumption is an important driving force of economic growth. Private consumption is the largest component of the gross domestic product of any economy. And household consumption is the major component of private consumption. As the wealth of the households grows, the households have a propensity for altering their spending patterns; some new goods enter into the consumption basket, and/or the weights of the existing goods have been changed within the consumption basket (Prais, 1953; Jackson, 2004).

Household behavior is dominated by two basic principles. The first one states that a household is free to choose any combination of consumption items but within the limits of resource availability. The second one is that that choice must be rational by considering all other possible alternatives. The priority comes into the picture when the affordability bounds the households to choose all of its desirable consumption items. The prioritization of consumption items makes the consumption patterns different among the households (Kasulis et al., 1979). The priority makes a household rational; the household first tries to consume necessary goods for survival. Relatively less priority goods come next (Lusch et al., 1978; Dickson et al., 1983). The choice and scope of alternatives play crucial role to change the consumption pattern rationally.

Douglas and Isherwood (1979) had described the household consumption patterns within the frame of three types of scales. In small-scale consumption, a larger part of total expenditure goes for consumption of food items. In medium-scale consumption, a relatively higher proportion of total expenditure goes for the purchase of consumption items with the advancement of consumer technology. In brief, when the income of the households increases the level of total consumption also increases; at the same time, the composition within the consumption basket also changes – from more foods to more advanced technology-based consumer goods.

Wittmayer, et al. (1994) had also suggested a new concept called 'standard package'. When a household chooses consumption items it chooses a group of items together – a package. All the households within an income class desire to choose the same group of products consistently; they maintain a standard of package. A consumer's desire to acquire consumption items are mainly based on the functioning of two things – the positions of the households in the space of production and its market, and in the space of consumption. The position in the production market gives the consumer a social status such as membership of the income classes, employment relations, etc. Such membership of an income classes determines the location in the consumption market by involving a definite 'standard package' of cultural preference, taste and preference of the society, manners, or habits of the people (Lamont and Molnár, 2001; Douglas and Isherwood, 1979).

The patterns of consumption are having two serious problems – over-consumption, and under-consumption. And both are present in the contemporary world. Poverty forces poor people who do not consume enough to meet their basic needs to make a short-term survival decision which would have long-term negative impacts on environments. The economic prosperity can lead to over-consumption of environmentally inefficient goods which would also have the logn-term negative impacts on environments. So, overall over-consumption and under-consumption both are leading to unsustainable economies. Likewise, it is possible to consume the goods and services in such a way so that it does not put the environment at risk. Sustainable consumption does not stimulate the demand for environmentally unsuitable and pollution creating products (Clark, 2007).

However, some policymakers doubt in reducing energy consumption by changing consumption patterns as all type of consumption is somehow associated with energy consumption, directly and indirectly and hence with the CO_2 emission also. It possible to produce goods and services without using any energy directly or even indirectly, with the existing knowledge of technology. The dependency on renewable resources has remained at the limit. Therefore, using no energy and emitting no CO_2 while producing goods and services is near to an impossible event (Alfredsson, 2004).

The energy use and the related CO_2 emission can be reduced to a limited level, in the short-run, by changing the consumption patterns. And in the long-run, as the economy grows, it would increase the energy consumption and related CO_2 emission (Cowell and Green, 1994). Hence, the only way to reduce the energy requirements and related CO_2 emission from the consumption of goods and services is to depend on the substitutability of energy sources in the long-run. The differences in energy intensity and related CO_2 emission intensity among the different consumption goods provide a scope to substitutes the higher intensity goods to the lower ones (Alfredsson, 2004). However, the availability of the energy sources used by the lower intensity goods and services is also an important aspect here. Therefore, if resources are available and the substitutability is possible, then substituting the higher energy and CO_2 emission intensity goods and services to the lower one can make reduce the total energy consumption in long-run.

2.3. Consumption Pattern and its Determinants

The household consumption patterns depend on some basic features of the households. Any changes in household characteristics influence the household consumption pattern (Katz-Gerro, 2004; Cohen, 1998; Bihagen, 1999). Any change in economic recourses of the household and/or other factors like consumers' culture makes difference in household consumption patterns (Koelln et al., 1995). The economic factors such as income of the households, prices of goods and services, and credit availability effect the consumption choices available to the households (Cohen, 1998; Bihagen, 1999).

On the other hand, every society aspires a certain desirable standard of consumption or pattern of consumption (Koelln et al., 1995). The society's aspiration about achieving the desirable consumption level set the 'consumption culture'. The consumption culture promotes one set of lifestyle and its consumption superior to the other; hence it creates the hierarchies among the different lifestyle and preference for consumption goods. However, the hierarchy of different lifestyle is not static, it may change continuously over time (Katz-Gerro, 2004). The hierarchies of such a consumption-based lifestyle are based on the factors like ethnicity, gender, class, age, education and so on. However, economic factor is the most important factor shaping hierarchy in consumption-based lifestyle.

The economic resources become an essential element enhancing the economic affordability of the consumers (Koelln et al., 1995; Bihagen, 1999; Wong and Yu, 2002). Apart from household income and household composition, the '*Urban Status*' is also a key factor for defining the consumption pattern (Cowell and Green, 1994; Wu, 1997; Lázaro et al., 2000). The effects of modernization, group preferences, commercial opportunities, and stylistic differences may make the differences in consumption patterns in urban and rural areas across the different income classes (Fan and Lewis, 1999; Semyonov et al., 1996).

The focal point of this chapter is to find the consumption patterns of households of different income classes across different settlement categories. The consumption patterns, however, are not static; it may vary over time, depending upon the various factors of household consumption. This chapter captures the change of household consumption patterns among the different categories of households over the study periods, 1993-94 to 2011-12. Analysis also focuses on whether these changes in household consumption patterns are significantly different among the different categories of households or not. And lastly, households would be classified and grouped into different clusters depending on the similarity and dissimilarity of their consumption patterns.

2.4. Sources of Data

The National Sample Survey Organization (NSSO) conducts large-scale sample survey on household consumption every year along with other socio-economic surveys. The NSSO also conducts a very large sample survey in every five-years on household consumption along with the employment and unemployment situation. The consumption expenditure data of NSS for 1993-94 (50^{th} round) and 2011-12 (68^{th} round) have been considered for this thesis. The NSSO has classified the settlement areas into two categories – rural and urban. And the Census of India had classified the urban area into six classes[14], class I to class IV. In this thesis, the million-plus (10 lakh and more) populated urban centers are treated as city and the rest of the urban areas as town. Therefore, the city, town and rural areas are considered as the three settlement categories for this thesis.

Bhattacharya and Nanda (2012) had classified the households into three categories based on their per capita expenditure. These are higher-income classes (HIC), middle-income classes (MIC) and lower-income classes (LIC).[15] This thesis has adopted this classification of households on the basis of per capita expenditure. According to Bhattacharya and Nanda (2012), the households containing the bottom 20 per cent of the people of an "income ladder" is treated as LIC households; the households containing the top 20 per cent population of the income ladder is considered as HIC households; the rest of the households in the middle of income ladder (middle 60 per cent of the population) is considered as MIC households.

2.5. Analytical Framework

Many researchers used the analysis of variance (ANOVA) and regression analysis (Cowell and Green, 1994) to determine the factors influencing the consumption pattern. The multi-dimensional scaling (MDS) method, though not common, is also tried by some researchers. Multi-dimensional scaling has been used to measure 'the Euclidean

[14] Class I (1,00,000 or more population), Class II (50,000 to 99,000), Class III (20,000 to 49,999), Class IV (10,000 to 19,999), Class V (5000 to 9999) and Class VI (below 5000).

[15] "Rural Energy Access and inequalities: An Analysis of NSS data from 1999-00 to 2009-10", TERI-NFA Working Paper No. 4, December 2012. Table-2 in page number 22.

distance'[16] which describes the consumption difference between different classes of population (Bihagen, 1999). A few economic studies had paid attention to the multi-dimensional nature of consumption patterns while comparing to them among the different income classes (Wish and Carroll, 1982). However, in some sociological and anthropological studies, use of multi-dimensionality of consumption patterns has been observed.

This method builds relations among the income classes based on their consumption patterns. In MDS, the two income classes with their similar consumption patterns will be called structurally equivalent, from the point of view of consumption (Talmud and Mesh, 1997). The indicator of such equivalency will be depicted by the distance between the income classes based on the similarity in the proportion of consumption patterns (Mazzocchi, 2008; Torgerson, 1952). However, in multi-dimensional scaling, the relative positions of the income classes are relative, not absolute. Therefore, the distance indicates the proximity of the distance, in a relative sense (Wish and Carroll, 1982).

The methodology adopted here is the combination of 'network image of social structure[17]' and the consumption behavior of the different segments of the society. The method would provide the "structural image of the relational pattern[18] to infer the relational proximity[19] of consumption item-groups". The basic idea of this method is to

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[16] The length of a line segment between two points in Euclidean space is called the Euclidean distance. Sometimes, it is also known as Pythagorean distance as it is measured in the Cartesian coordinates of two points by using the Pythagorean Theorem.

[17] It is a visual presentation of network of Income classes.

[18] It says about the pattern of consumptions in relationship between income classes. By the word 'relational' it means the relationship or connection between two consumption patterns of two household groups.

[19] The relational proximity is the measurement of the distance in relationship of two groups in certain aspect.

connect the actor's *relational properties* (such as consumption patterns) with the actor's *social attributes* (such as income classes). The consumption levels of different income classes vary according to their aspiration for achieving higher consumption level (Talmud and Mesh, 1997; Maoz et al., 2003). Given the availability of consumption set, the economic affordability of the households and their characteristics determine the expected level of consumption a household wants to aspire.

Any method which scales down the two income classes into the same measuring platform by capturing the multi-dimensionality of different consumption items would be a desirable diagnostic in consumption analysis (Talmud and Mesh, 1997). The diagnostic tool would choose the similarity or dissimilarity among the income classes within the multi-dimension of consumption items (Wish and Carroll, 1982; Torgerson, 1952). The degree of similarity or dissimilarity can be judged by the proximity of the distance among the relational consumption pattern among the income classes. If two income classes reveal similar relations to consumption items, then it is called that they are structurally equivalent in relational consumption patterns (Maoz et al., 2003).

2.6. Model Specification

Let us define C_{ik} as the value of consumption expenditure by the ith income class on kth consumption bundle. So, the total value of consumption expenditure by the ith income class will be as:

$$R_i = \sum_{k=1}^{k} C_{ik} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots..(2.1)$$

A matrix by (i x k) dimensions can be constructed on the relation between income class i and consumption item group k. From this matrix, the consumption of any bundle by any income class can be identified easily (Mazzocchi, 2008; Maoz et al., 2003). The structural equivalence principle is considered to be the guiding philosophy and an empirical tool to investigate the similarity among the different income classes with their spending on the various consumption goods (Cox and Cox, 2008; Talmud and Mesh, 1997). Technically speaking, the income classes have similar consumption patterns among themselves; and they have zero distance (structural) among themselves (Cox and Cox, 2008; Mazzocchi, 2008).

The dissimilarity (or the distance, d_{ij}) in consumption pattern between ith income class and jth income class can be presented through Euclidean distance as:

$$d_{ij} = \sqrt{\sum_k \left(\frac{C_{ik}}{R_i} - \frac{C_{jk}}{R_j}\right)^2} \quad ; i \neq j, k \neq i, j \neq k \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.2)$$

Where, C_{ik} is the consumption of the kth bundle by the ith income class and R_i is the total consumption by the ith income class (Wish and Carroll, 1982). The ratio, $\frac{C_{ik}}{R_i}$, reveals the relative share of kth consumption item group to total consumption by the ith income class. The ratio, $\frac{C_{jk}}{R_j}$ reveals the same for jth income class (Cox and Cox, 2008). $\left(\frac{C_{ik}}{R_i} - \frac{C_{jk}}{R_j}\right)$ measures the difference between the two relative shares of kth consumption item group out of total consumption for both the income classes. The same thing is calculated for all consumption items to find the value of Euclidean distance, d_{ij}, between ith and jth income classes in relation to consumption pattern.

The principle of structural equivalency is used here as an indicator of dissimilarity which is specified by the pair-wise distances (d_{ij}) among all income classes with consumption patterns of all consumption items at the household level (Cox and Cox, 2008). A square matrix of distances d_{ij}, can be formed with all sorts of distances among the different combinations of two income classes (Mazzocchi, 2008; Talmud and Mesh, 1997). Every element of this matrix will represent the relational distances between two specific income classes in relation to consumption pattern. The MDS method helps to decompose this ‘distance matrix’ into two or more dimensional spaces (Wish and Carroll, 1982; Maoz et al., 2003).

In a two-dimensional Euclidean space, the relative location of two income classes provides the indicator of the ‘degree of dissimilarities’ of consumption patterns for two income classes. Closer to the location, similar would be the consumption patterns. In other words, the zero distance between the two income classes implies the structural equivalence of their consumption. In MDS method, the network analysis is compiled with the consumer behavior approach (Talmud and Mesh, 1997; Maoz et al., 2003).

Torgerson (1952) had introduced the Classical[20] MDS (cMDS) which is based on linear algebra. The real distances are treated in cMDS as Euclidean distances. In the application of cMDS, the data on distances are not real distances, but some proximity of that data. And when those proximities are applied in classical cMDS, then these proximities behave like the data of real distances. The proximities have been derived from the correlation matrices (Wish and Carroll, 1982; Mazzocchi, 2008).

Let’s assume the squared proximity matrix, $D^{(2)} = [(d_{ij})^2]$. Where, every element of the proximity matrix is just a square of the distance. Now, let us construct the centering matrix[21], $Q_n = \mathbf{I} - \mathbf{n}^{-1}\mathbf{1}\mathbf{1}'$. Where, $\mathbf{I}$ is the identity matrix of dimension (n x n), and $\mathbf{1}$ is the column vector of ‘n’ numbers of ones, and $\mathbf{1}'$ is the transpose of it. Therefore, $\mathbf{1}\mathbf{1}'$ gives the square matrix of dimension (n x n) whose all elements are ones. Here, ‘n’ is the number of income classes. The use of a centering matrix helps to scale down the elements

[20] There are different forms of MDS methods such as classical, metric, non-metric and generalised. The classical MSD is the most popular and widely used by the researchers.

[21] Centering matrix is a symmetric and idempotent matrix which gives two same effects in two cases; i) multiplied with a vector, and ii) subtracting the mean of the vector from every elements of the vectors.

by mean without affecting the basic nature of the matrix (Cox and Cox, 2008; Wish and Carroll, 1982).

A double centering[22] method will help to remove mean from both columns and rows. By applying the double centering method, a new matrix Z can be obtained as

$$\mathbf{Z} = -\frac{\mathbf{1}}{\mathbf{2}}\,\mathbf{Q}\,\mathbf{D}^{(\mathbf{2})}\mathbf{Q} \quad \text{………………………….(2.3)}$$

The Z matrix is similar to the distance matrix or proximity matrix, D. Only difference is that by applying the double centering method the distance matrix, D, has been scaled down to Z matrix through mean removal of column and row vectors (Cox and Cox, 2008; Maoz et al., 2003). The coordinate matrix X is required to be derived from this Z matrix, such that $\mathbf{Z} = \mathbf{X}\,\mathbf{X}'$.

Suppose, 'm' is the number of dimensions chosen for the analysis. Then 'm' numbers of the largest positive eigenvalues have been calculated by applying factor analysis (Wish and Carroll, 1982; Mazzocchi, 2008). Suppose, λ_1, λ_2, …..,λ_m are the largest eigenvalues of scalar matrix Z and the corresponding 'm' eigenvectors are e_1, e_2, …., e_m. Then, the coordinate matrix X can be formed as:

$$\mathbf{X} = \mathbf{E_m}\mathbf{R_m^{1/2}} \quad \text{…………………………………(2.4)}$$

Where, E_m is the matrix of 'm' eigenvectors and R_m is the diagonal matrix of 'm' eigenvalues of scalar matrix Z. The m-dimensional spatial configuration of the n income classes can be derived from the coordinate matrix, X. In the classical MDS method, the coordinate matrix X can be obtained from the eigenvalue decomposition of the scalar

[22] Without double centering, the values of coordinate matrix could not have unique values. The double centering method provides unique solution of coordinate matrix X, by dimension reducing. Therefore, in cMDS, the result finds the centered configuration and the pairwise distances match the corresponding Euclidean distances, perfectly. This dimension reduction method is same as the principal component analysis (PCA).

product matrix, Z (Cox and Cox, 2008). The one-dimensional cMDS method considered only the largest eigenvalue and its corresponding eigenvector to calculate the coordinate matrix. Two-dimensional cMDS methods considered the largest two eigenvalues and their corresponding eigenvectors to configure the coordinate matrix (Cox and Cox, 2008; Mazzocchi, 2008).

2.7. Change in Households Food and Non-Food Expenditures

The total household expenditure is divided into food expenditure and non-food expenditure. It is expected from the Engel function theorem that if the household has relatively lower disposable income, it spends more of its income on food. As income of that household increases, the household's expenditure on non-food expenditure also increases more than that of food expenditure. That means the relative importance of expenditure shifts from food expenditure to non-food expenditure when there is an increase in household income. On the other hand, it is expected that the lower-income households will spend relatively higher percentage of total expenditure on food than that of relatively higher-income households. The reverse is the case for non-food expenditure.

Table-2.1: Percentage Share of Food and Non-Food Expenditure of Households in India

Expenditure Item Group	Share in Total Consumer Expenditure (%)									
	Rural					**Urban**				
	1987-88	1993-94	1999-00	2004-05	2011-12	1987-88	1993-94	1999-00	2004-05	2011-12
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Food	64.0	63.2	59.4	55.0	50.2	56.4	54.7	48.1	42.5	41.1
Non-Food	36.0	36.8	40.6	45.0	49.8	43.6	45.3	51.9	57.5	58.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Sources: Various Reports of NSSO on Consumer Expenditure

Table 2.1 shows the percentage shares of total expenditure on food and non-food items during 1987-88 to 2011-12. The basic data is based on the consumption expenditure survey of NSSO. The percentage share of expenditure on food is decreasing continuously and steadily since 1987-88 for rural and urban areas, both. The food expenditure share was 64 per cent of total expenditure for rural households in 1987-88 and it has come down to 50.2 per cent of total expenditure in 2011-12. For the urban households, it was 56.4 per cent in 1987-88 and has come down to 41.1 per cent in 2011-12. The percentage share for the non-food expenditure of rural households was only 36 per cent (much lower than food expenditure) in 1987-88, and it increased over time continuously and reached 49.8 per cent in 2011-12. Similar be the case for urban households; it is increased from 43.6 per cent in 1987-88 to 58.9 per cent in 2011-12.

2.8. Changes in Consumption Pattern by Items

NSS survey classifies the consumption items into 25 items or groups. The list of 25 items can be seen from Table 2.2 which is showing the household consumption patterns in two-time periods, 1993-94 and 2011-12 across different settlement categories such as rural, town, and city.

The consumption pattern of household expenditure is represented by the percentage shares of consumption items-groups out of the total expenditure. Overall, it can be seen from Table 2.2 that the percentage shares of all food items-groups had gone downward for all the three settlement areas, such as rural areas, towns, and cities, during the study period, 1993-94 to 2011-12. Only the ‘beverages & processed food’ is an exception in the food basket. The percentage shares of expenditure on beverage & processed food have gone up for all households in 2011-12.

The cereals as an item in the household consumption basket are very important. The percentage shares of cereal consumption expenditure remain at a higher level irrespective of the settlement category. However, it had declined for all three areas by a significant level. But, the share of cereal for rural areas reached the level of share of cereal consumption for towns as it was in 1993-94. Similarly, the share of cereal consumption for towns had declined and reached the level of share of cereals of cities as it was in 1993-94. The consumption expenditure for pulses had revealed similar patterns of consumption behaviour.

Among the non-food consumption items, the fuels & lights are the most key component which had contributed a momentous change in consumption pattern. The percentage share of expenditure on fuels and lights had been increased for all the three settlement categories. However, the share of expenditure on fuels & lights in rural areas is significantly more than that for towns and cities for both the periods; and that of towns is also more than that of cities for both periods.

A similar pattern had been observed for clothing and footwear. But, the difference is that the percentage shares of expenditure on clothing & footwear had been declined for all the three settlement categories over the same study period. Because of spreading urbanization in the last three decades, the share of expenditure on housings has increased for all three areas. However, it is highest for cities, and least for rural areas. Share for medical care expenditure had increased during the study periods – for all the settlement categories. One key point to be noted here is that the share of medical care expenditure out of total expenditure is largest for the average household in a rural area in both periods. In relation to expenditure on health, the expenditure on hygiene items remained with the same patterns.

The overall patterns of the share of expenditure on consumption items related to hygiene remain unchanged over the periods for all three areas. The recreation & entertainment had got larger importance in Indian during the same study periods. The percentage share of it had increased significantly, but the shares remained at a lower level for all three settlement categories. The share of transportation expenditure had gone up by a significant level for all three areas. However, that share is highest for households in cities and lowest for households in the rural area. Similar patterns of expenditure had seen for personal services.

Rural Area: The cereal is considered as the major component in household expenditure as it provides the ingredients for preparing the staple meal. The dependency of rural people on cereals for the foods makes a larger percentage of the household expenditure goes for the purchase of cereals in the rural area. Almost one-fourth of the total expenditure in rural households in 1993-94 went only for cereals. However, it had declined to 12.23 per cent in 2011-12. The second largest consumption item at an average rural household in 2011-12 is fuel & lights with 9.39 per cent of total consumption expenditure. It was 7.55 per cent of total expenditure in 1993-94 – the fourth largest component. Whereas in 1993-94, the second-largest component was the milk & milk products with 9.75 per cent of total expenditure in rural households, and it became the third-largest in 2011-12 with 9.22 per cent of total expenditure.

In 1993-94, the clothing & footwear was the third largest component with 8.75 per cent of total expenditure and it became the fourth largest one in 2011-12 with 8.06 per cent of total expenditure, more or less maintaining its relative importance in rural households. The vegetables are the other component that remains important, in both periods.

Table 2.2: Comparison of Household Consumption Pattern in 1993-1994 and 2011-12 across Settlement Categories (Percentage of Total expenditure)							
Sl. No.	Aggregated Items	Rural Area		Town		City	
		1993-94	2011-12	1993-94	2011-12	1993-94	2011-12
1	Cereals	24.96	12.23	15.77	8.28	10.49	6.57
2	Pulses	4.11	3.32	3.40	2.52	2.93	2.09
3	Vegetables	6.21	4.91	5.36	3.62	5.98	3.46
4	Edible Oil	4.53	3.83	4.46	2.87	4.42	2.61
5	Milk & Milk Products	9.75	9.22	9.72	8.25	10.47	8.01
6	Egg, Fish & Meat	3.42	3.62	3.56	3.13	3.10	2.49
7	Sugar	3.13	1.88	2.58	1.29	1.98	1.03
8	Salt	0.19	0.19	0.15	0.13	0.12	0.10
9	Spices	2.52	2.28	2.02	1.71	1.76	1.42
10	Fruits	1.78	1.97	2.50	2.46	3.20	2.42
11	Beverages & Process Food	4.27	5.92	6.90	6.98	8.35	8.51
12	Pan, Tobacco & Intoxicants	3.27	0.83	2.50	0.64	2.07	0.45
13	Fuel & Lights	7.55	9.39	6.76	8.11	6.46	7.76
14	Clothing & Footwear	8.75	8.06	8.80	7.62	7.61	7.30
15	Housing	1.36	1.29	4.62	1.10	5.38	0.78
16	Household Effects	0.42	3.06	0.57	3.35	0.58	2.98
17	Education	1.54	4.02	3.67	8.19	4.72	9.09
18	Medical	0.96	7.53	1.60	6.62	1.04	6.55
19	Hygiene	2.50	2.43	2.85	2.52	2.94	2.43
20	Recreation & Entertainment	0.45	1.27	0.93	2.14	1.10	2.30
21	Transportation	2.97	6.29	4.96	9.77	7.38	10.89
22	Jewellery	0.38	1.39	0.36	1.57	0.17	1.07
23	Other Personal Goods	2.43	0.32	2.51	0.49	2.54	0.52
24	Personal Services	2.45	4.57	3.01	6.17	4.31	8.32
25	Consumer Taxes & Cesses	0.11	0.16	0.45	0.44	0.88	0.85
	Total	100	100	100	100	100	100
	MPCE (MRP) (Rs.)	**274.05**	**949.98**	**413.03**	**1630.6**	**595.2**	**2506.9**

Sources: Various Reports of NSSO on Consumer Expenditure;
Note: MPCE stands for Monthly Per Capita Expenditure;
MRP stands for Mixed Recall Period;
Aggregated Items are as per NSSO.

The other consumption items which have increased their shares in total expenditure during the period, 1993-94 to 2011-12, in rural households are beverages & processed food, education, medical expenditure, transportation, personal services, housing, household effects, recreation & entertainment. On the other hand, the other consumption items whose consumption shares out of total expenditure have fallen during the study period are pulses, edible oils, sugar, fruits, pan & tobacco. Overall, the percentage of shares of food items had gone down and that for some the non-food items had been gone up in rural households.

***Town**:* The percentage share of cereals has been gone down from 15.77 per cent in 1993-94 to 8.28 per cent in 2011-12. However, it became the largest component in 2011-12, just after transportation. And, it reached the level of share of cereals of cities as it was in 1993-94. The fuels & lights and milk & milk products become the second, the third-largest components in the consumption basket of an average household in towns in 2011-12. The share of fuel & lights out of total expenditure gone up from 6.76 per cent in 1993-94 to 8.11 per cent; whereas that of milk & milk products gone down from 9.72 per cent, the second-largest share after cereals, in 1993-94 to 8.22 per cent share in 2011-12.

Education became the next important consumption items-groups in households in towns in 2011-12. Housing, medical care, recreation & entertainment, jewelry, and personal services are the other consumption items-groups with increasing relative importance in household consumption basket in towns. On the other hand, beverages & processed foods, clothing & footwear, hygiene are the other major items whose consumption shares within the household consumption basket have gone down over the study period.

***City**:* The changes in consumption patterns happened mostly in households in cities; there are some remarkable changes in households during the study periods. Many other non-food consumption items-groups crossed the relative share of cereals. Instead of cereals, education expenditure has become the single largest component for an average city household in 2011-12. As education has a strong association with urbanization, the increasing urbanization in India after liberalization had changed the nature of household expenditure in city life. Over the last three decades, the expenditure on education related goods and services had increased significantly. The expenditure on education comprised almost 9 per cent of total household expenditures in 2011-12 and it was only about 4.72 per cent in 1993-94.

The largest component is transportation, as it is also strongly associated with increasing urbanization, with 10.89 per cent in 2011-12 (increased from 7.38 per cent in 1993-94). The share of expenditure on personal services also increased from 4.31 per cent. The increasing services base in city life is an important indicator of the standard of life. Other major items whose relative shares in consumption basket had gone up are fuels & lights, medical cares, etc. on the other hand, the relative share of expenditure on cereals, vegetables, edible oil, milk & milk products, beverages & process foods – all the food products, and on clothing & footwear had gone downward in city life during the study period.

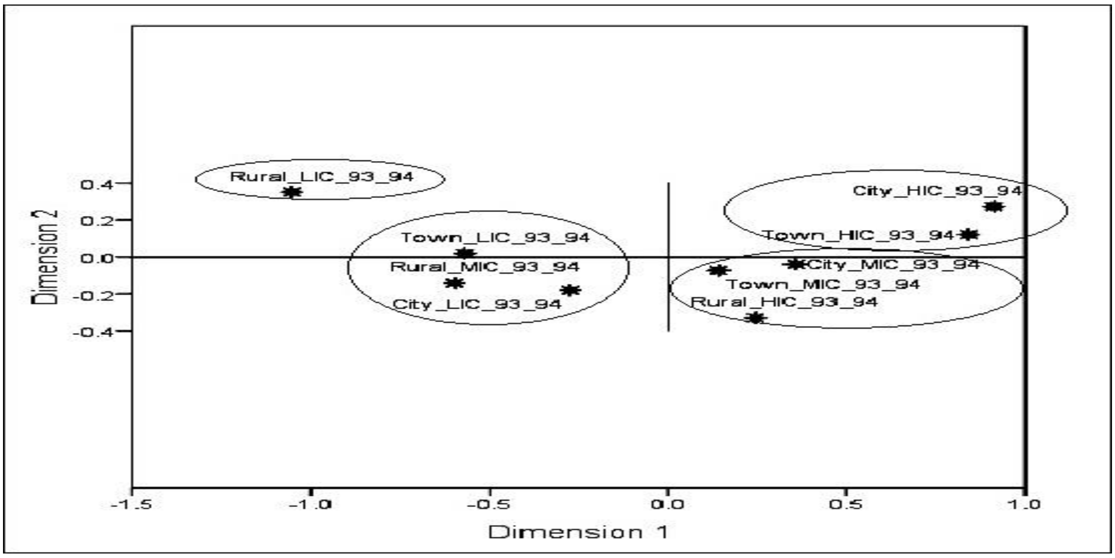
2.9. Multi-dimensional Scaling (MDS)

The MDS is a most useful tool to visualize the Euclidean distances of proximities. The MDS is applied here to visualize the proximities of consumption patterns of average households of three different income classes in three different settlement categories. For simplification of the analysis, the total consumption items were classified into 25 categories. The SPSS 16 software was used to calculate MDS.

MDS: Two- Dimensional Scaling for 1993-94

The two-dimensional scaling of different categories of households according to their consumption pattern in 1993-94 has been presented in Figure 2.1. The Rural lower-income class (Rural_LIC) households standalone – far proximities with other categories of households. It can be said that the consumption patterns of rural lower-income class households are different from the rest. The second cluster of households with close proximities includes rural middle-income households and lower-income households from towns and cities. However, the consumption pattern of lower-income class households in cities was a bit different from the rest of these two.

Figure 2.1: MDS for Indian Households Consumption Patterns in 1993-94



Source: Author's calculation

Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively;
93_94 stands for the year 1993-94;
MDS stands for Multidimensional Scaling.

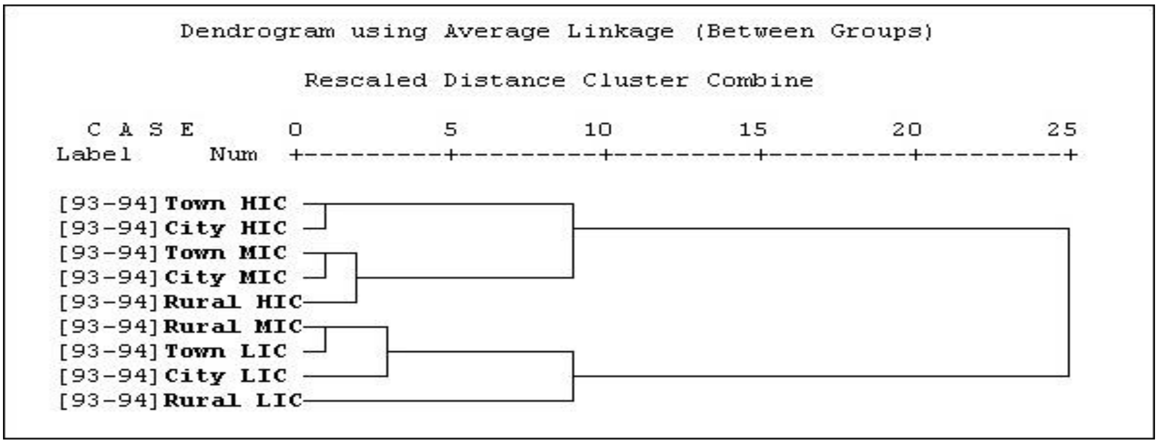
According to the proximity through dimension 1,[23] the next closest one is town middle income class households. And surrounding it, the rural higher income class

[23] The dimension 1 is showing the consumption patterns associated with the highest eigenvalue

households and city middle income class households are in close proximity. And the consumption patterns of the high-income class households in towns and cities in 1993-94 are different from others. And the consumption patterns of these two categories of households relatively more similar among themselves.

The outcome of MDS from consumption patterns of different household types is also supported by the *Cluster Analysis*. The Dendrogram used for the cluster analysis of consumption patterns of different types of households in 1993-94 is showing similar results as provided in Figure 2.2. The advantage of the cluster analysis is that the grouping among the similar types of households is possible here. It can be identified overall four basic clusters of households with the similar type of household consumption patterns. The first cluster comprises only one type of household i.e. lower-income class households in the rural area (Rural-LIC), say Cluster A.

Figure 2.2: Dendrogram (Between Groups) of MDS for 1993-94

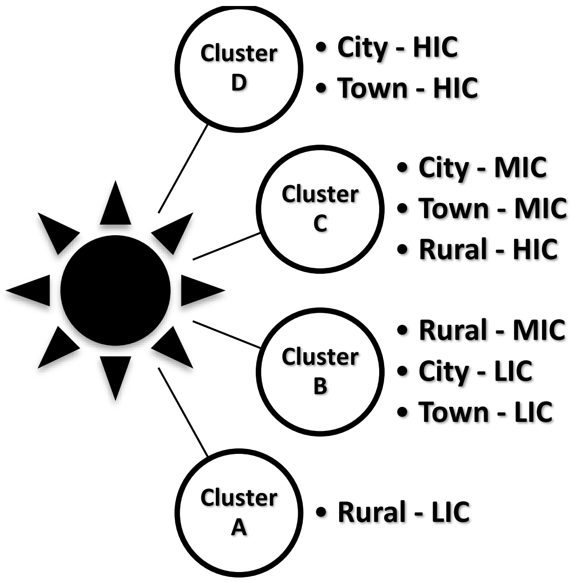


Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively;
93_94 stands for the year 1993-94;
MDS stands for Multidimensional Scaling.

The second cluster can be drawn by combination of Rural-MIC and Town-LIC households and then come together with City-LIC households (say, Cluster B). The third type of cluster can be made with MIC households in towns and cities and then combined with Rural-HIC households (say, Cluster C). And lastly, HIC households in towns and cities come together and form a different cluster – the fourth cluster (say, Cluster D).

From the above analysis, it can be seen that consumption pattern varies over time and in different settlement categories. The consumption pattern is even different among income classes. From the above MDS analysis and Cluster analysis of the consumption data in 1993-94, all the households have been classified into four clusters. The details of the classification are shown in Figure 2.3. Since, all the analyses have been done in the rest of the chapter by considering the year 1993-194 as the base year, the classification of the households for 1993-94 as shown in Figure 2.3 is followed.

Figure 2.3: Clustering Households



Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.

To sum up, to capture the energy and environmental implications of differential household consumption, households can be classified into three income classes (such as lower, middle, and higher) across the three settlement categories (such as the rural, town, and city). Therefore, total nine types of households have been derived by combinations of three income classes and three settlement categories. The expenditure of food consumption items out of total expenditure had come down continuously. The analysis shows that the household consumption patterns for those three income classes across those three settlement categories are different, and the differences among such consumption patterns are different in 2011-12 from 1993-94. The method of multidimensional scaling has been applied to check the similarity or dissimilarity of the consumption patterns of the nine types of household classes. Results show that the consumption patterns are very different among the income classes. Being in extreme, the consumption patterns of lower-income households in rural areas are very different from that of higher-income classes of towns and cities. To classify them, the cluster analysis has been done. And it gave similar result and classified the income classes into four Clusters. This chapter established that there is difference in household consumption patterns among the different households in India. Further, households are classified into four Clusters depending upon the similarity of their consumption patterns.

The classification of the households into four different clusters has been used in rest of the chapters, especially in chapters 5 and 6. The analysis has been done either across income classes, such as lower-, middle- and higher-income classes, or across settlement categories such as rural, town and city. After discussing the differential household consumption patterns in this chapter, the next chapter does focus on macro aspect of the energy intensity. In chapter three, the energy intensity and energy-related CO_2 emission intensity of every sectors of the Indian economy would be calculated for the period 1993-94 and 2007-08. Those intensities will be used in calculating the indirect energy uses and related CO_2 emission at household level, in chapter five.

Chapter - 3

Energy Input-Output Analysis

3.1. Background

Bullard and Herendeen (1975) stated that "when you consume anything, you are consuming energy". Every good has some energy within it, bio-chemically. Human being can put some extra energy within goods when they transform it into another form of goods, during the production process. For any kind of product transformation, energy is needed – directly or/and indirectly. Therefore, when someone consumes any good not only s/he consumes its physical materials, but also consumes some energy, required to produce or transform it into another good along with it.

The state of Indian economy has gone through a rapid change in its structure, in the last three decades after the economic liberalization has been taken in 1991. The Kyoto Protocol had been implemented by that time, with some exemption for India. Over the years, the environmental sustainability got importance in policymaking.

Energy-related CO_2 emission is the largest portion of total CO_2 emission. Therefore, to deal with the issues of climate change, the energy studies become important in policymaking. Many studies have been conducted on CO_2 emission and climate change, but most of them are of energy-related CO_2 emission. Wu and Chen (1989) had applied energy input-output analysis with hybrid-unit to calculate energy intensity in Taiwan for the year 1971-84. It showed that almost 85 per cent of all economic sectors had shown a decline in total primary energy intensity.

Howarth et al. (1993) had shown the trends in the intensity of the final energy demand for five OECD countries for the period 1973-1988. They had suggested that the change in the structure of an economy might lead to substantial changes in energy intensity, and that is unrelated to changes in technological coefficients. Unlike in China and OECD countries, the studies on energy intensity got relatively less attention in India.

This chapter analyses the environmental sustainability of the different sectors of the Indian economy specifically on the dynamics of changing energy intensity and CO_2 emission intensity of different sectors of the Indian economy since 1991. This chapter is based on energy input-output analysis. And through this method, the energy intensity, direct and total, of every sector of the Indian economy would be calculated during the study periods, 1993-94 and 2007-08. Then energy-related CO_2 emission intensity, direct and total, will also be calculated for every sector in both periods.

3.2. Input-output Analysis in Energy Studies

The input-output analysis got a new direction towards energy analysis after the oil crises in the early 1970s. The oil-producing countries had formed a cartel called OPEC[24] in the early 1970s and cut the oil production drastically. As a result, the price of petroleum went up suddenly at a high level. To cope up with this oil crisis internationally, the energy uses or specifically the energy uses at its optimal level received much focus in the field of economics as well as environmental science. Those scholars were expertise in input-output modeling they also got attracted to the incorporation of energy use into input-output modeling. The input-output models were developed extensively with its energy use components, and it got an extended name, Energy Input-Output (EIO) Analysis. In recent years, the climate change analysis is getting structured with the extended input-output analysis (Kerkhof et al., 2009b).

The basic input-output technique was developed by the Nobel Laureate Wassily Leontief during the 1930s and 1940s. He framed the input-output model out of a system of linear equations. Each equation represents a sector and defines the dispersal of output of one sector across the economy – into all sectors as inputs to them. These inter-industry transactions had been represented in form of matrix to frame the input-output model. Since then the input-output model had become the most widely applied tool in economic research. And the method is also extended and applied to various fields of studies. The energy and environmental extensions of the input-output model have been applied in this thesis.

[24] OPEC stands for Organization of Petroleum Exporting Countries.

The eminent scholars such as Cumberland (1966), Strout (1967), Ayres and Kneese (1969), Bullard and Herendeen (1975), and many others had worked extensively to incorporate the energy use within the input-output framework. Since then, the extended version of input-output analysis including energy usage and related environmental activities got substantial attention in the literature on energy studies. The energy extension of the Leontief input-output framework was developed and used widely in the 1970s to get a set of linear energy coefficients that define energy use per unit of the monetary value of the output of sectors of the economy. However, initially, it had some methodological and practical limitations.

Bullard and Herendeen (1975) had introduced the 'hybrid units' approach to addressing the principal weakness of the EIO analysis. Then energy coefficients resulting from the EIO analysis with hybrid units conform to a set of 'energy conversion conditions'[25] (Lindner and Guan, 2014). The EIO analysis assumes the inter-industry prices of energy are uniform across all consuming sectors.

Leontief and Ford (1972) were the pioneers in applying the input-output method for measuring the pollution level of the emissions from consumption of energy items. They had evaluated the strategies for controlling emissions in major polluting industries in the US economy. Since then the related input-output studies have been used extensively to analyze the problems related to energy usage and environmental issues.

Miller and Blair (2009) worked on the input-output framework to make it an 'Extension' for covering the theoretical ground of advanced applications of input-output analysis to the subjects like energy and environments. They had also worked on multiplier

[25] These conditions conform the internal consistency of accounting for physical energy flows in the economy.

analysis to get the quantitative effect of the energy consumption and pollution generation while inter-sectorial interactions.

Gould and Kulshreshtha (1986) were among the initial researchers who had analysed the importance of final demand, energy use & energy conservation, and structural inter-dependency of the economy. Breuil (1992) had also applied the input-output model to calculate the emissions of SO_2 and NO_x in different sectors in France from 1985 to 1989. He had also compared his results with the actual emissions figures to evaluate the input-output model.

Hung et al. (2007) had applied the input-output model to estimate the effects of solid waste generation, directly and indirectly. They had also tried to find some association between economic progress and management of solid waste at the regional level. Chen and Wu (1994) had applied the input-output framework to estimate the impact of 14 sources of changes in demand for electricity for the sectors in Taiwan during 1976 and 1986.

Hawdon and Pearson (1995) had applied a '10-sector input-output model' to analyse the interaction among energy, environment, and economic activities. They also tried to estimate the effects of different policies such as a change in income taxes, final demand, and sectoral structural change. Proops et al. (1996) had applied the input-output method to estimate the implications of lifecycle of eight types of sources of electricity aiming to reduce different types of pollutant emitting such as CO_2, SO_2, and NO_x. They have analysed the impact of the change of energy use quantitatively through the input-output framework.

Chen (2001) has analysed the Leontief input-output model to investigate the impact of mitigating CO_2 emission strategies in Taiwan. Limmeechochai and Suksunternsiri

(2007) have applied the input-output model to estimate the energy intensity coefficients and emission factors for all final consumption in Thailand. Mäenpää and Siikavirta (2007) have estimated the GHGs emissions in association with the final consumption and international trade during 1990-2003 by applying the input-output model.

However, many studies had tried to calculate the energy efficiency in different sectors of the economy in different countries, mostly the Netherlands, Spain, China, the USA, the UK, and Taiwan. Calculating the energy intensity of the produced goods and services was not the sole objective of those studies, however, the energy intensity was calculated while tried to see the impact of change in final demand, import, export, etc. through the input-output analysis (Kerkhof et al., 2009b). However, fewer studies have been done so far on calculating the emission intensity such GHGs intensity, CO_2 intensity, and other emitted gases.

In the Indian context, very few studies have been done in energy economics so far as compared to other countries. Some of the works in this context in India are works of Mukhapadhaya (2002), Parikh et al. (2009), and Ghosh and Dutta (2016). However, most of the studies are with a much more aggregated level in sectoral aggregation. However, more disaggregation would give the more appropriate estimates. This present study is based on total 111 aggregated sectors of the Indian economy that is much more sectors considered here than any other studies done so far in India in this field.

3.3. Sources of Data

The major source of input-output analysis is the "Input-Output Transaction Tables" (IOTTs) of "Central Statistical Organization" (CSO) for the year 1993-94 and 2007-08. Then the matrix of a 'commodity by commodity' is considered for the analysis as it gives commodity flows across the sectors. However, the IOTTs of 1993-94 had only 115 sectors, and the IOTTs of 2007-08 have 130 sectors. Therefore, a rearrangement of sectoral aggregation has been done to make these two IOTTs comparable. In this thesis, a total of 111 aggregated sectors are formed for both periods.

For making the input-output tables comparable in different years, it is required to present them on a constant price basis. The changing price level will distort the monetary value of the transactions. Just a mere comparison of the monetary transactions in two tables does not give a true picture of the actual amount of resource movement across the sectors. The application of the price indices here can make the transaction at a constant price. Since the IOTTs are calculated in current prices, then the Wholesale Price Index (WPI) has been used to convert the IOTTs of 2007-08 of current price into a constant price, by considering 1993-94 as the base year.

The monetary transactions in input-output tables, even if at a constant price, can't ensure the energy balance in energy flow across the sectors in the economy. Therefore, researchers are using a hybrid form of input-output analysis by converting the energy resources into physical units (Lindner and Guan, 2014). The energy statistics from different official reports of the different Ministries have been used to convert it into a hybrid IOTTs. These are Coal Statistics, Electricity Statistics by CEA, Power Statistics of respective Ministries, Petroleum and Natural Gas Statistics and the database of TERI.

The net calorific values (NCV) of different sources of energy are also used from different governmental documents to convert the energy flow in energy units. Therefore, by combining the datasets of IOTTs, WPI, Energy Statistics, and NCV (Net Calorific Value) and CO_2 emission factors are applied to the energy input-output model to calculate the sectoral energy intensity of the Indian economy for the periods of 1993-94 and 2007-08. Besides, to estimate the energy-related CO_2 emission intensity, energy-specific emission factors (EFs) were required. India-specific emission factors have been used from different government documents, separately for 1993-94 and 2007-08. However, in the absence of India-specific EFs, the default emission factors for IPCC guidelines have been used.

3.4. Analytical Framework

The methodology of this chapter is banked on the input-output framework with extension to energy and environmental applications. The objective of this chapter is to find the energy intensity and energy-related CO_2 emissions intensity of total 111 numbers of aggregated sectors of Indian economy for the years 1993-94 and 2007-08.

3.4.1. Basic Input-output Framework

According to the basic rules of input-output analysis, the production process of each sector can be presented by a vector. The vector with the structural coefficients express the relationship between the inputs and output of that sector (Miller and Blair, 2009). The total output of sector i, (X_i) can be used as an intermediate for the other production sector and rest is for the final demand for consumption. Therefore, the output equation can be represented by:

$$\boldsymbol{X_i = \sum_j x_{ij} + Y_i} \qquad (3.1)$$

Where, $\boldsymbol{X_{ij}}$ represents the 'value' of input transferred from i^{th} sector to j^{th} sector. Here, the number of rows and columns are defined by i and j, respectively. $\boldsymbol{Y_i}$ denotes the total final demand for goods and services of i^{th} sector. The final demand comprises the production for households and government consumption, the export to the other countries, fixed capital formation, and the change in inventories.

By assuming the constant returns to scale of the production process, the output (or the supply) equation of any sector can be written as:

$$\boldsymbol{X_i = \sum_j a_{ij} X_j + Y_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.2)}$$

Where the coefficient $\boldsymbol{a_{ij}}$ is called 'technological coefficients', it represents the output flow from i^{th} sector to j^{th} sector for per unit of sector's j output. A set of 'n' number of linear simultaneous equations will represent one economy's productive system. Each equation describes the distributions of that sector's output across all other sectors of the economy (Miller and Blair, 2009). A matrix form of algebraic operation is useful for solving the whole systems of the equations of the economy.

The equation (3.2) can be written by applying the basic concepts of matrix operation as:

$$\boldsymbol{x = (\mathbf{I} - A)^{-1} y} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.3)}$$

Where, $\boldsymbol{A}$ is the technological coefficients matrix, $\boldsymbol{y}$ is final demand vector, $\boldsymbol{x}$ is the vector of total outputs and I is the unit matrix. The expression (3.3) is the basic matrix form of input-output analysis. The inverse matrix, $(\mathbf{I} - \boldsymbol{A})^{-1}$ is known as the 'Leontief inverse matrix' (Miller and Blair, 2009).

3.4.2. Energy Input-output Analysis

Herendeen (1974) had introduced the energy balance conditions for the energy flows. The energy conservation conditions for all the economic sectors j can be represented as the energy embodied in output $\mathbf{x_j}$ of any sector is equal to the amount of energy embodied in inputs of all sectors, $\mathbf{z_{ij}}$. It is coupled with primary energy used as input, $\mathbf{g_{kj}}$, which is non-zero only for primary sectors. These conditions can be expressed mathematically as given below (Miller and Blair, 2009):

$$\boldsymbol{\alpha_{kj}}\mathbf{x_j} = \sum_{\mathbf{i=1}}^{\mathbf{n}} \boldsymbol{\alpha_{ki}}\mathbf{z_{ij}} + \mathbf{g_{kj}} \quad \text{......................................} (3.4)$$

Where $\boldsymbol{\alpha_{kj}}$ is the total energy of type k required to produce one unit of output in the monetary value of sector j; $\mathbf{x_j}$ is the output of sector j in monetary value; $\mathbf{z_{ij}}$ is the monetary value of the output of sector i is consumed in sector j, as input; and $\mathbf{g_{kj}}$ is the total energy output of an energy sector (Miller and Blair, 2009). Let us define G as:

$$G = [g_{kj}]_{m\ X\ n} = \begin{cases} g_k\ for\ same\ energy\ sectors; k = j \\ 0, otherwise \end{cases}$$

Non-zero elements for energy sectors come only along the principal diagonal of the matrix, G.

$$\boldsymbol{\alpha}\hat{\boldsymbol{X}} = \boldsymbol{\alpha}\,\boldsymbol{Z} + \boldsymbol{G} \quad \text{……………………………………} (3.5)$$

By solving equation (3.5), the total energy coefficient can be obtained as:

$$\boldsymbol{\alpha} = \mathbf{G}\,(\hat{\mathbf{X}})^{\mathbf{-1}}(\mathbf{I} - \mathbf{A})^{\mathbf{-1}} \quad \text{…………………………………} (3.6)$$

Now, the hybrid method of input-output analysis is applied by measuring the energy sectors in physical units (energy units) and the other non-energy sectors in monetary units (Lindner and Guan, 2014). The transformation of sectoral transactions matrix and output vector in hybrid technique can be specified as given below (Miller and Blair, 2009):

$$Z^* = [z^*_{ij}]_{n\,X\,n} = \begin{cases} Z_{ij} \text{ where i is a non} - \text{energy sector} \\ e_{kj} \text{ where k is an energy sector} \end{cases}$$

$$X^* = [x^*_i]_{n\,X\,1} = \begin{cases} x_i \text{ where i is a non} - \text{energy sector} \\ g_k \text{ where k is an energy sector} \end{cases}$$

The direct and Leontief matrices, respectively, in hybrid technique is given below:

$$\mathbf{A}^* = \mathbf{Z}^*\left(\widehat{\mathbf{X}}^*\right)^{-\mathbf{1}} \text{and, } \mathbf{L}^* = (\mathbf{I} - \mathbf{A}^*)^{-\mathbf{1}}$$

The sectoral total energy coefficients matrix is shown in Equation (3.7) below (Miller and Blair, 2009).

$$\boldsymbol{\alpha} = \mathbf{G}\,(\hat{\mathbf{x}}^*)^{-\mathbf{1}}\mathbf{L}^* \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.7)}$$

It can also be said that the total primary energy coefficient is a linear combination of primary energy coefficients of every sources of energy. Therefore,

$$\boldsymbol{\epsilon}_{\boldsymbol{total\,primary\,.j}} = \boldsymbol{\epsilon}_{\boldsymbol{Coal\,.j}} + \boldsymbol{\epsilon}_{\boldsymbol{Crude\,Oil\,.j}} + \boldsymbol{\epsilon}_{\boldsymbol{Natural\,Gas\,.j}} + \boldsymbol{\epsilon}_{\boldsymbol{Non-thermal\,Electricity\,.j}}$$

Here, petroleum products (refined petroleum) and thermal electricity are considered as the secondary sources of energy. That is the season, these two energy sources are not considered to avoid double-counting while calculating the total primary energy coefficient.

3.4.3. Environmental Input-output Analysis

The environmental input-output analysis can incorporate the environmental issues and helps the policymakers to know about the sectoral role in dealing with environmental issues. It can deal with various issues related to the environment, most importantly, the material flows across the sectors in the economy, waste generation, solid waste management, and emission of pollutants by the industrial sectors of the economy.

The input-output tables measured in monetary units have to be combined with energy and environmental data in physical unit. This hybrid method can able us to follow the physical energy balance principles. That's why it comes out as a consistent and systematic approach to assess the effects of environmental issues on the economic activity and the impact of economic activity on the environment, through the environmental input-output analysis. It also helps to measures those impacts quantitatively and therefore provides valuable insights for economic planning.

Almost similar to the energy input-output analysis, the environmental variables are incorporated in the hybrid version of the extended input-output model. The hybrid input-output model has been already explained in the chapter. As this chapter also intends to calculate the CO_2 emission intensity, information of the CO_2 'emission factors' is used as:

$$\mathbf{C} = \mathbf{F}\,\mathbf{G}\,(\hat{\mathbf{x}}^{*})^{-\mathbf{1}}\mathbf{L}^{*} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.8)$$

Where, C is denoting the matrix for CO_2 emission intensity of all the sectors, F is the matrix for emission factors of all the sources of energy.

3.5. Energy Intensity and CO_2 emission Intensity in India

3.5.1. Direct Primary Energy Intensity

The sector which is using the most primary energy directly for one rupee of its output is the 'Coal Tar Products'. Among the all 111 aggregated sectors considered in this study, the 'Coal Tar Product' sector is the most direct energy-intense sector over the study periods. However, the direct primary energy intensity has come down for this sector from 12.54 MJ/Rupee in 1993-94 to 11.46 MJ/Rupee. The second most direct primary energy-intense sector was the 'Cement' sector in 1993-94 with 4.33 MJ/Rupee which is much lower than the 'Coal Tar Products'.

Table 3.1: Top 20 Sectors for highest TPEI (Direct) in 1993-94 and 2007-08

1993-94			2007-08		
Non-energy Sectors		MJ/Rupee	Non-energy Sectors		MJ/Rupee
1	Coal Tar Products	12.54	1	Coal Tar Products	11.46
2	Cement	4.33	2	Non-ferrous Basic Metals	5.49
3	Fertilizers	3.35	3	Iron, Steel, and Ferro Alloys	4.83
4	Iron, Steel, and Ferro Alloys	2.65	4	Cement	3.57
5	Structural Clay Products	2.42	5	Organic Heavy Chemicals	3.04
6	Inorganic Heavy Chemicals	2.07	6	Fertilizers	2.74
7	Paper, Paper Prods. & Newsprint	2.05	7	Iron and Steel Casting & Forging	2.65
8	Synthetic Fibres, Resin	1.52	8	Iron and Steel Foundries	1.93
9	Organic Heavy Chemicals	1.24	9	Misc. Metal Products	1.22
10	Railway Transport Services	1.22	10	Inorganic Heavy Chemicals	1.02
11	Iron and Steel Casting & Forging	1.13	11	Other Electrical Machinery	0.94
12	Other Non-metallic Mineral Prods.	1.03	12	Other Chemicals	0.67
13	Other Chemicals	0.90	13	Structural Clay Products	0.65
14	Non-ferrous Basic Metals	0.73	14	Other Non-metallic Mineral Prods.	0.64
15	Paints, Varnishes, and Lacquers	0.72	15	Paper, Paper Prods. & Newsprint	0.59
16	Tea and Coffee Processing	0.59	16	Synthetic Fibres, Resin	0.45
17	Hand Tools, Hardware	0.50	17	Paints, Varnishes, and Lacquers	0.30
18	Beverages	0.47	18	Jute, Hemp, Mesta Textiles	0.21
19	Hotels and Restaurants	0.46	19	Wood and Wood Products	0.18
20	Rubber Products	0.46	20	Misc. Textile Products	0.17

Source: Author's calculation

Note: TPEI stands for Total Primary Energy Intensity; MJ stands for Megajule;
Rupee is Indian Rupee at constant price (Base year = 1993-94)
The Serial numbers are ranks in ascending order.

The energy intensity of the 'Cement' sector has declined to 3.57 MJ/Rupee in 2007-08 and the rank also declined to fourth in 2007-08. Whereas, in 2007-08, 'Non-ferrous Basic Metals' and 'Iron, Steel and Ferro Alloys' became the second and third most direct primary energy-intense sectors with 5.49 MJ/Rupee and 4.83 MJ/Rupee, respectively. The top ten sectors of direct primary energy intensity for both periods are given in Table 3.1, below.

The direct primary energy intensity of most of the energy sectors have declined over the period. However, the result is not so straight forward. Some sectors have become more energy-intensive. It is evident from Table 3.1 that direct primary energy intensity has increased for 'Non-ferrous Basic Metals', 'Iron, Steel, and Ferro Alloys', 'Organic Heavy Chemicals', 'Iron & Steel: Casting & Forging', 'Iron & Steel: Foundries', 'Misc. Metal Products' etc. over the period, 1993-94 to 2007-08. Apart from 'Coal Tar Products' and 'Cement', the other important sectors in which the direct primary energy intensity had declined are 'Fertilizers' (3.35 MJ/Rupee to 2.74 MJ/Rupee) and 'Inorganic Heavy Chemicals' (1.24 MJ/Rupee to 1.02 MJ/Rupee).

3.5.2. Total Primary Energy Intensity

The direct energy intensity is not including sufficient information on energy embodied-ness per unit of output of any sector. The total primary energy intensity (TPEI) can capture the total energy required directly and indirectly. The ranking of the sectors based on the total primary energy requirements is something different from that of direct energy for both periods.

The 'Other Transportation Equipment' sector stood first in absorbing total primary energy, 24.33 MJ/Rupee in 1993-94. The rankings of the top ten sectors based on total primary energy intensity for both the periods have been given below, in Table 3.2. The 'Coal Tar Products' sector was at third in that line with 13.59 MJ/Rupee. Although the TPEI has come down to 13.35 MJ/Rupee in 2007-08, it stands first in that intensity.

Table 3.2: Top 20 Sectors for highest TPEI (Total) in 1993-94 and 2007-08

1993-94			2007-08		
	Non-energy Sectors	**TPEI (MJ/Rupee)**		**Non-energy Sectors**	**TPEI (MJ/Rupee)**
1	Other Transport Equipment	24.33	1	Coal Tar Products	13.35
2	Motor Vehicles &Motor Cycles	15.12	2	Non-ferrous Basic Metals	9.93
3	Coal Tar Products	14.21	3	Iron, Steel, and Ferro Alloys	8.69
4	Bicycles, Cycle-rickshaw	13.59	4	Fertilizers	7.77
5	Mica	7.54	5	Iron and Steel Casting & Forging	6.97
6	Cement	6.42	6	Cement	6.26
7	Iron, Steel, and Ferro Alloys	5.97	7	Iron and Steel Foundries	6.17
8	Fertilizers	5.85	8	Organic Heavy Chemicals	5.70
9	Iron and Steel Casting &Forging	4.93	9	Inorganic Heavy Chemicals	4.63
10	Paper, Paper Prods. &Newsprint	4.37	10	Other Transport Services	4.19
11	Iron and Steel Foundries	4.27	11	Other Non-metallic Mineral Prods.	4.12
12	Inorganic Heavy Chemicals	4.21	12	Industrial Machinery (F & T)	4.08
13	Structural Clay Products	3.86	13	Drugs and Medicines	3.98
14	Synthetic Fibres, Resin	3.66	14	Other Electrical Machinery	3.98
15	Organic Heavy Chemicals	3.61	15	Misc. Metal Products	3.68
16	Non-ferrous Basic Metals	3.56	16	Structural Clay Products	3.58
17	Communication	3.26	17	Iron Ore	3.48
18	Misc. Metal Products	3.17	18	Soaps, Cosmetics &Glycerine	2.98
19	Paints, Varnishes, and Lacquers	3.06	19	Electr. Indust. Machin. & Wire & Cables	2.80
20	Hand Tools, Hardware	2.92	20	Hand Tools, Hardware	2.73

Source: Author's calculation

Note: TPEI stands for Total Primary Energy Intensity; MJ stands for Megajule;
Rupee is Indian Rupee at constant price (Base year = 1993-94)
The Serial numbers are ranks in ascending order.

It is very interesting to note here that some high energy-intense sectors have got benefited from other sectors that followed energy-saving technology over the period. The top 2 sectors in 1993-94 were very high in TPEI, even though they were at lower ranks for direct energy consumption. Therefore, these two top sectors having higher energy intake through the other non-energy input requirements indirectly, in 1993-94.

On the other hand, the top sector which is taking most energy, directly and indirectly, is the 'Coal Tar Products' in 2007-08. Only half of the top ten sectors (see Table 3.2) in direct energy intensity in 1993-94 (see Table 3.1) were in the top ten sectors in total energy intensity in 1993-94. On the other hand, in 2007-08, out of ten top sectors for direct energy intensity, a total of nine sectors are in the top ten rankings for total energy intensity (see Table 3.2).

The two points can be drawn here, first, the difference between total and direct energy intensities have declined from 1993-94 to 2007-08. It reflects the relative decline in indirect energy requirements over the periods. The second, a clear decline in total energy intensity is some sectors that were more energy-intense indirectly in their production process.

3.5.3. Direct Energy-related CO_2 Emissions

The CO_2 emission due to energy used directly is the subject matter of discussion in this section. The top ten CO_2 emission intense sectors for both periods have been documented in Table 4.3. The 'Coal Tar Products' sector was the most emitting sector in 1993-94 with 89.83 tonnes of CO_2 (t CO_2) per lakh rupees of production. The 'Thermal Electricity' sector and 'Cement' sector came second (69.59 t CO_2 per lakh rupees) and third (40.84 t CO_2 per lakh rupees) in 1993-94. Since, only the CO_2 emission due to energy used is considered that is why it is natural to get almost the same sectors at its top ranking, as it was in direct energy uses (see Table 3.1).

Table 3.3: Top Ten Sectors with Direct CO_2 Emission Intensity (DIRECT) in 1993-94 and 2007-08 in India					
1993-94			2007-08		
	Production Sectors	t CO2/Lakh Rupees		Production Sectors	t CO2/Lakh Rupees
1	Coal Tar Products	89.83	1	Non-ferrous Basic Metals	53.55
2	Thermal Electricity	69.59	2	Thermal Electricity	52.29
3	Cement	40.84	3	Iron, Steel & Ferro Alloys	45.05
4	Iron, Steel, and Ferro Alloys	25.59	4	Coal Tar Products	39.94
5	Structural Clay Products	24.53	5	Cement	33.37
6	Paper, Paper Prods. & Newsprint	19.39	6	Iron and Steel Casting & Forging	25.70
7	Inorganic Heavy Chemicals	17.46	7	Iron and Steel Foundries	17.95
8	Fertilizers	14.19	8	Misc. Metal Products	11.47
9	Other Non-metallic Mineral Prods.	13.32	9	Other Electrical Machinery	09.23
10	Motor Vehicles & Motor Cycles	12.42	10	Structural Clay Products	07.44

Source: Author's calculation

Note: t CO2 stands for Tonnes of CO_2 emission;
Rupee is Indian Rupee at constant price (Base year = 1993-94);
Lakh is one-tenth of a million
The Serial numbers are ranks in ascending order.

The almost same pattern is followed for 2007-08; the sectors which stand in the top ten rankings in direct energy intensity are also in the top ten rankings in energy-related direct CO_2 emission intensity. It is also evidence that the energy-related CO_2 emission intensity has declined significantly during the study period, e.g. 'Coal Tar Products' from 89.83 t CO2 per lakh rupees in 1993-94 to 39.94 t CO2 per lakh rupees in 2007-08. However, the sectors like 'Non-ferrous Basic Metals' and 'Iron, Steel & Ferro Alloys' have gone more CO2 emitting in direct energy uses over time.

3.5.4. Total Energy-related CO_2 Emissions

The energy-related CO_2 emission due to consumption of total energy is presented here in Table 3.4, below.

Table 3.4: Top Ten Sectors with Total CO_2 Emission Intensity (TOTAL) in 1993-94 and 2007-08 in India					
1993-94			**2007-08**		
	Production Sectors	**t CO2 / Lakh Rupees**		**Production Sectors**	**t CO2 / Lakh Rupees**
1	Coal Tar Products	101.54	**1**	Non-ferrous Basic Metals	80.59
2	Thermal Electricity	91.93	**2**	Iron, Steel, and Ferro Alloys	67.14
3	Cement	56.83	**3**	Thermal Electricity	65.18
4	Iron, Steel, and Ferro Alloys	51.87	**4**	Iron and Steel Casting & Forging	51.42
5	Other Transport Equipment	47.69	**5**	Iron and Steel Foundries	45.47
6	Iron and Steel Casting & Forging	41.54	**6**	Coal Tar Products	44.32
7	Paper, Paper Prods. & Newsprint	37.90	**7**	Cement	39.42
8	Iron and Steel Foundries	35.72	**8**	Industrial Machinery (F & T)	27.64
9	Structural Clay Products	34.69	**9**	Misc. Metal Products	27.42
10	Inorganic Heavy Chemicals	32.50	**10**	Other Electrical Machinery	27.39

Source: Author's calculation
Note: t CO2 stands for Tonnes of CO_2 emission;
Rupee is Indian Rupee at constant price (Base year = 1993-94);
Lakh is one-tenth of a million
The Serial numbers are ranks in ascending order.

The most CO_2 emitting (energy-related) sector in 1993-94 was 'Coal Tar Products' (101.54 t CO2 per lakh rupees); whereas the 'Non-ferrous Basic Metals' is the most CO_2 emitting sector (80.59 t CO2 per lakh rupees) in 2007-08. The topmost CO_2 emission sectors like 'Coal Tar Products', 'Thermal Electricity', and 'Cement' sectors have become relatively less CO_2 emitting sectors in 2007-08. However, the 'Ferrous' and 'Non-ferrous Basic Metals' sectors have gone more intense in CO_2 emission (energy-related) over the period.

3.5.5. Total Primary Energy Intensity over Different Primary Energy Sources

Table 3.5 shows the relative decomposition of total primary energy intensity over four primary energy sources.

Table 3.5: Top Ten Sectors with Total Primary Energy Intensity (TPEI) over Different Primary Energy Sources.

		Coal & Lignite	Natural Gas	Crude Oil	Hydro & Nuclear Electricity
	Aggregated Sectors (Top Ten)	**(1)**	**(2)**	**(3)**	**(4)**
	1993-94				
1	Other Transport Equipment	8.87	2.89	12.05	0.51
2	Motor Vehicles & Motor Cycles	5.10	1.74	7.98	0.29
3	Coal Tar Products	10.10	0.78	3.26	0.07
4	Bicycles, Cycle-rickshaw	5.09	1.65	6.56	0.30
5	Mica	2.39	0.88	4.13	0.14
6	Cement	5.54	0.46	0.28	0.13
7	Iron, Steel and Ferro Alloys	5.01	0.40	0.48	0.09
8	Fertilizers	1.80	2.21	1.76	0.09
9	Iron and Steel Casting & Forging	3.87	0.53	0.43	0.11
10	Paper, Paper Prods. & Newsprint	3.58	0.40	0.28	0.10
	2007-08				
	Aggregated Sectors (Top Ten)	**(1)**	**(2)**	**(3)**	**(4)**
1	Coal Tar Products	4.13	0.49	8.71	0.03
2	Non-ferrous Basic Metals	7.89	0.29	1.68	0.07
3	Iron, Steel, and Ferro Alloys	6.27	0.76	1.59	0.07
4	Fertilizers	0.58	1.25	5.90	0.04
5	Iron and Steel Casting & Forging	4.84	0.40	1.66	0.06
6	Cement	3.40	0.70	2.09	0.06
7	Iron and Steel Foundries	4.23	0.49	1.40	0.05
8	Organic Heavy Chemicals	0.55	0.36	4.74	0.05
9	Inorganic Heavy Chemicals	0.95	0.55	3.06	0.06
10	Other Transport Services	0.20	0.12	3.86	0.02

Source: Author's calculation

Note: All figures are in Megajoule/ Rupee; Rupee is Indian Rupee at constant price (Base year = 1993-94); TPEI stands for Total Primary Energy Intensity;
Sum of all four energy sources come up with the total primary energy intensity;
The Serial numbers are ranks in ascending order;

In 1993-94, for 'Other Transport Equipment' the main sources for high energy intensity are *Crude Oil* (12.05 MJ/Rupee) and *Coal & Lignite* (8.87 MJ/Rupee). The same pattern can be seen in the case of 'Motor Vehicles & Motor Cycles' in 1993-94 (7.98 MJ/Rupee from *Crude Oil*, and 5.10 MJ/Rupee from *Coal & Lignite*), 'Bicycles & Cycle-rickshaw', and 'Mica'. The other sectors which are among the top ten energy-intense sectors in 1993-94, are also energy-intense due to *Coal & Lignite* more than other sources of energy (see Table 3.5). Sources like *Natural Gas* and *Hydro & Nuclear Electricity* are relatively less important than *Coal & Lignite,* and *Crude Oil*.

One interesting change has gone through over the period – that is in 2007-08, the major source of the total primary energy intensity for the 'Coal Tar Products' sector in the *Crude Oil*, not *Coal & Lignite* as it was in 1993-94. The energy intensity for the 'Fertilizers' sector has also gone towards *Crude Oil* heavily. Otherwise, the sectors based on ferrous or non-ferrous metals are more dependent on *Coal & Lignite* as the major sources of energy directly and indirectly. And, the chemical-based sectors are based on *Crude Oil*, directly and indirectly, for its energy requirements.

3.5.6. Total CO_2 Emission Intensity over Different Primary Energy Sources

Table 3.6 shows the source-based decomposition of the total CO_2 emission intensity of the top ten sectors in both the study periods. Almost all the sectors are heavily CO_2 emitting due to the heavy use of *Coal & Lignite* source of energy in 1993-94.

However, *Natural Gas* is responsible for high CO_2 intensity in the 'Thermal Electricity' sector (17.96 MJ/Rupee) and the *Petroleum Products* source is equally responsible for energy-related CO_2 emission in the 'Other Transport Equipment' sector (21.90 MJ/Rupee).

	Table 3.6: Top Ten Sectors with Total CO_2 Emission Intensity over Different Energy Sources	Coal & Lignite	Natural Gas	Crude Oil	Petroleum Products
	Aggregated Sectors (Top Ten)	(1)	(2)	(3)	(4)
	1993-94				
1	Coal Tar Products	95.00	4.08	0.07	2.39
2	Thermal Electricity	71.86	17.96	0.06	2.05
3	Cement	52.02	2.43	0.07	2.32
4	Iron, Steel, and Ferro Alloys	46.97	2.10	0.08	2.72
5	Other Transport Equipment	21.68	3.46	0.66	21.90
6	Iron and Steel Casting & Forging	36.04	2.76	0.08	2.66
7	Paper, Paper Prods. & Newsprint	33.43	2.10	0.07	2.30
8	Iron and Steel Foundries	30.41	2.52	0.08	2.71
9	Structural Clay Products	30.20	1.08	0.10	3.30
10	Inorganic Heavy Chemicals	26.15	4.16	0.06	2.12
	2007-08				
	Aggregated Sectors (Top Ten)	(1)	(2)	(3)	(4)
1	Non-ferrous Basic Metals	77.31	1.54	0.04	1.70
2	Iron, Steel, and Ferro Alloys	61.44	4.05	0.03	1.62
3	Thermal Electricity	57.52	4.19	0.07	3.40
4	Iron and Steel Casting & Forging	47.45	2.14	0.04	1.79
5	Iron and Steel Foundries	41.41	2.58	0.03	1.46
6	Coal Tar Products	40.37	2.59	0.03	1.34
7	Cement	33.34	3.71	0.05	2.31
8	Industrial Machinery (F & T)	24.59	1.78	0.03	1.24
9	Misc. Metal Products	25.49	1.09	0.02	0.82
10	Other Electrical Machinery	25.19	0.98	0.03	1.20

Source: Author's calculation

Note: All the figures are in t CO_2 emission per Lakh Rupees; Rupee is Indian Rupee at constant price (Base year = 1993-94); TPEI stands for Total Primary Energy Intensity;
Sum of all four energy sources come up with the total primary energy intensity;
The Serial numbers are ranks in ascending order;

The scenario for 2007-08 is the same. The energy source of *Coal & Lignite* is the major and almost only sector which is responsible for a large share in energy-related CO_2 emission intensity among the top ten emitting sectors in 2007-08.

On the whole, the energy input-output analysis in this chapter had revealed that the coal tar product sector was the most intense energy-consuming sector, for direct energy use in 1993-94. The next three direct energy-intense sectors were cement, fertilizers, and iron & steel. The coal tar product sectors still maintained its first rank in 2007-08 also. The non-ferrous basic metal sector became the second most intense sector in 2007-08.

During the same time, the iron & steel sector became more direct energy-intense, but cement and fertilizer became less. Now, if we consider the total primary energy intensity, then the ‘Other Transportation Equipment’ sector stood first in absorbing total primary energy, 24.33 MJ/Rupee in 1993-94. The ‘Coal Tar Products’ sector was at third in that line with 13.59 MJ/Rupee. Although the TPEI has come down to 13.35 MJ/Rupee in 2007-08, the coal tar products sector stands first in that intensity.

In the case of CO_2 emission, the coal tar products, thermal electricity, and cement were the topmost polluter (direct) in 1993-94. In 2007-08, the non-ferrous basic metal, thermal electricity, and iron & steel were the top three polluters. One important aspect, we got from this study that in almost all sectors, CO_2 emission intensity had declined drastically. And the similar picture we got when we study the total CO_2 emission intensity.

It can be said from the above results that the overall energy intensity of the top energy-intense sector has declined from 1993-94 to 2007-08 over the fourteen years, with some exceptions. Then energy-related CO_2 emission intensity has also declined over the same period. There was clear evidence that the energy requirement from indirect ways has narrowed over the study period. The same result is reflected in the case of energy-related CO_2 emissions. For sources of energy, the high intense sectors were highly dependent on *Coal & Lignite*, and *Crude Oil*. However, for energy-related CO_2 emissions, the heavy use of *Coal & Lignite* is the solely responsible source over the same periods.

This chapter provides the measures of energy intensity and energy related CO_2 emission intensity for goods and services produced in every aggregated sectors of Indian economy for the years 1993-94 and 2007-08. A certain amount of energy is required to produce every good and then responsible to certain amount of CO_2 emission in production sectors. This energy embodied inside the goods, through other intermediate sectors, reach to households for final consumption.

The next chapter will analyse the direct energy consumption at household level and the related CO_2 emission. Every household consume certain amount of energy for lighting, cooking and heating purposes. Some of the major sources of energy in India, as documented in various reports of NSSO, are firewood, coal, dung cake, kerosene, electricity and LPG. The next chapter will focus on the differential consumption pattern of energy items of the different types of households as classified in this chapter. Analysis will also focus on the CO_2 emission due to energy use directly at household level. Then, the Chapter 5 would measure the total energy consumption by the households. To calculate total energy consumption, the indirect energy would be adding up to the direct energy consumed. The findings of this chapter would help us to measure the energy consumption indirectly by the households, and hence to calculate the total energy consumption in the chapter five.

Chapter – 4

Direct Energy Requirements

and

Related CO_2 Emission

4.1. Background

The total household energy requirements can be classified into two groups viz., direct energy, and indirect energy (Vringer and Blok, 1995). Direct energy is used through the consumption of sources of energy such as firewood, coal, kerosene, electricity, and LPG, directly at the household level. Every household uses a certain level of energy directly for cooking, lighting, heating, comfort, and entertainment purposes. A basic minimum level of energy is required by every household for maintaining the minimum standard of living.

On the other hand, indirect energy is the energy that is consumed by a household indirectly through the consumption of other non-energy goods and services. A household consumes varieties of non-energy goods and services. To produce these goods and services at least a certain amount of energy is consumed in the production sector as an input. By consuming goods and services, a household is indirectly consuming the energy which was used in the production sector as inputs.

India is rapidly becoming one of the major CO_2 emitters in the world. The per capita emission for India is still lower in comparison to the other developed countries; it is lower than many developing countries also. However, the rapid economic growth of India is catching the eyes of the global policymakers as a major CO_2 emitter in the coming future.

A few studies have focused on industrial sectors only, while others concentrated on households. Some studies had been done on household energy which were mainly small sample survey-based observations. There are very few studies which are based on the household energy requirements at all India level. However, there is no such study has been conducted in India to analyse household energy use by different income classes and different settlement categories.

This chapter focuses on direct energy requirements only. The total energy requirements and related CO_2 emissions will be dealt with in the subsequent chapters. The estimations of direct energy requirements and related CO_2 emissions have been covered in this chapter. Not only just for an average Indian household, but the direct energy requirements and related CO_2 emission would be estimated for the households in different settlement categories belonging to different income classes. Direct energy consumption is implied when the sources of energy have been consumed by households. Therefore, all energy items used by Indian households have been considered in this analysis.

The next section of this chapter deals with the sources of data required. It is followed by the methodology used to estimate the direct energy requirement and related

CO_2 emissions at the household level. Next, analysis has been done for the direct energy requirement, energy item-wise, of an average Indian household in 1993-94 and 2011-12. Then it is extended to the analyses on an average household of different income classes across different settlement categories.

After that, direct energy-related CO_2 emissions are estimated by energy item-wise, for an average Indian household in 1993-94 and 2011-12. Similar to the direct energy, CO_2 emission analysis is also extended to the households of different income classes across different settlement categories. A comparative analysis has been done between the periods of 1993-94 and 2011-12 to capture the changing scenario indirect energy use at the household level.

4.2. Sources of Data

The information on monetary values (physical values for some items also) of every consumption item has been collected from the household consumption expenditure survey of the National Sample Survey Office (NSSO). For making compatibility with the input-output analysis in the subsequent chapters, the data on household consumption has been derived from the NSSO survey of years 1993-94 (50th round) and 2011-12 (68th round).

The energy price information is used from the Energy Statistics published by different Ministries of the Government of India and the consumer price indices. Net calorific values for each energy items are used to convert the physical term into energy unit, Mega Joule (MJ). For calculating the energy-related CO_2 emissions, the item-specific emissions factors are used here.

4.3. Analytical Framework

There are three types of settlements – rural, towns, and cities (i = 1, 2, 3), and three types of income classes – lower, middle, and higher-income classes (j = 1, 2, 3). There are 14 possible energy sources used in Indian households, according to various NSSO reports. They include coke, firewood, electricity, dung cake, kerosene, coal, LPG, charcoal, candle, gas, petrol, diesel, other fuels, and lubricants.

Let the monetary value of direct energy consumption of k^{th} source is denoted by ME_k. This monetary value of energy consumption can be converted into the physical value of energy consumption (PE_k) by using energy prices (P_k), as:

$$\boldsymbol{PE_k = \frac{ME_k}{P_k}} \quad \text{...(4.1)}$$

Let, $PE_k^{i,j}$ be denoted by the physical value of k^{th} source of energy consumed by the household from j^{th} income class in i^{th} settlement area. Therefore, $\sum_{i=1}^{3} PE_k^{i,j} = PE_k^{j}$ is the total physical energy from the q^{th} source of energy consumed by the j^{th} income class households. And, $\sum_{j=1}^{3} PE_k^{i,j} = PE_k^{i}$ is the total physical energy from k^{th} source of energy from i^{th} settlement category.

4.3.1. Calculation of direct energy consumption

Let e_k be the energy conversion coefficient for k^{th} source of energy. By multiplying PE_k^i by e_k, the direct energy in the energy unit (E_k^i) from k^{th} source can be obtained for the i^{th} settlement category. Therefore,

$$\boldsymbol{E_k^i = PE_k^i e_k = \sum_{j=1}^{3} PE_k^{i,j} e_k} \quad \text{...............................(4.2)}$$

Similarly, the direct energy in energy unit from k^{th} source for j^{th} income class (E_k^j) can be obtained as:

$$\boldsymbol{E_k^j = PE_k^j e_k = \sum_{i=1}^{3} PE_k^{i,j} e_k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.3)$$

The direct energy from k^{th} source consumed by the Indian households (E_k) can be obtained as:

$$\boldsymbol{E_k = \sum_{j=1}^{3} E_k^j = \sum_{j=1}^{3} PE_k^j e_k = \sum_{j=1}^{3}\sum_{i=1}^{3} PE_k^{i,j} e_k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4.4)$$

Or,

$$\boldsymbol{E_k = \sum_{i=1}^{3} E_k^i = \sum_{i=1}^{3} PE_k^i e_k = \sum_{i=1}^{3}\sum_{j=3}^{3} PE_k^{i,j} e_k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.5)$$

And the total direct energy consumed from all types of sources of energy by the Indian households can be obtained as:

$$\boldsymbol{E = \sum_{k=1}^{14} E_k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.6)$$

4.3.2. Calculation of emission from energy consumption

For the calculation of total CO_2 emission, the source-specific emission factors have to be used along with source-specific direct energy consumption. Let us assume that the CO_2 emission factor for k^{th} energy source is EF_k, then the total CO_2 emission from energy use can be obtained as:

$$\boldsymbol{C_k = E_k EF_k = \sum_{j=1}^{3} EF_k E_k^j = \sum_{j=1}^{3} EF_k PE_k^j e_k = \sum_{j=1}^{3}\sum_{i=1}^{3} EF_k PE_k^{i,j} e_k} \quad \ldots(4.7)$$

Or,

$$\boldsymbol{C_k = E_k EF_k = \sum_{i=1}^{3} EF_k E_k^i = \sum_{i=1}^{3} EF_k PE_k^i e_k = \sum_{i=1}^{3}\sum_{j=1}^{3} EF_k PE_k^{i,j} e_k} \quad \ldots(4.8)$$

And total direct CO2 emission from combusting all types of sources of energy is, then,

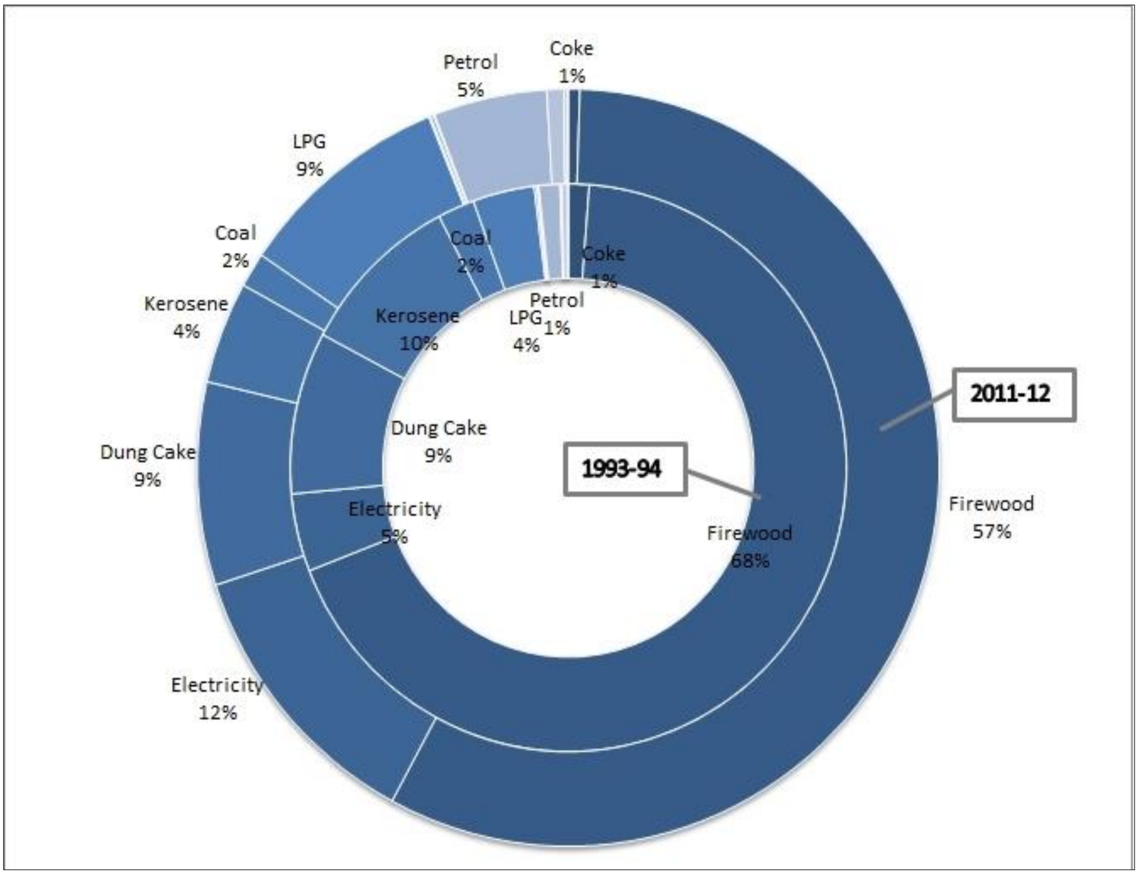
$$\boldsymbol{C = \sum_{k=1}^{13} C_k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.9)$$

4.4. Direct Energy Use at Indian Households

An average Indian household used almost 333.20 MJ of energy per capita per month in 1993-94. It has increased to 420.24 MJ of energy per capita per month in 2011-12. Use of firewood is predominant and it is the most important source of energy in Indian households. Despite the rapid increase in the usages of modern and sophisticated sources of energy, firewood still remains in top position. Out of the total direct energy consumption, 68 per cent came from firewood in 1993-94; and there is a slight decline, it is almost 57 per cent in 2011-12. Though the percentage share of firewood had been declined out of total energy consumption, but the energy consumption from firewood in absolute term had gone up from 226.18 MJ to 241.13 MJ per capita per month, during the same period.

Kerosene was the second largest (10 per cent) sources of energy directly used in Indian households in 1993-94; however, it has lost its relative importance in 2011-12 (4 per cent only). The per capita monthly consumption of kerosene has been declined from almost 32 MJ in 1993-94 to 18.34 MJ in 2011-12. Similar is the case for dung cake. The dunk cake was the third-largest (9 per cent) source of direct energy in Indian households in 1993-94 and it remains the same as in 2011-12. During the same period, the direct energy consumption from coal is also remaining at the same proportion, at 2 per cent of total direct energy consumed.

Figure 4.1: Percentage Share of Monthly Per Capita Direct Energy Usage in Indian Households in 1993-94 and 2011-12



Source: Author's calculation

The electricity consumption has registered the maximum increase among other sources of energy. During the same period, per capita monthly electricity consumption has gone up from only 14.78 MJ (5 per cent of total direct energy consumption) to almost 50.88 MJ; it is almost three times the increase in direct energy consumption in an absolute sense.

LPG and petrol are the other important sources which have gone up – LPG: from 4 per cent to 9 per cent and petrol: 1 per cent to 4 per cent. The rapid increase in LPG connection and usage of personal vehicles are the major causes of this huge jump. In an absolute sense, the LPG usage has increased from 12 MJ monthly per capita to 39 MJ monthly per capita, almost up by three times. Petrol has been used even four times more during the same period; from 4 MJ monthly per capita in 1993-94 to 20.80 MJ monthly per capita in 2011-12.

In a brief, the relative importance of so-called traditional sources of energy like firewood, dung cake, coal, and kerosene have been gone down, whereas that of modern sources of energy like electricity, LPG, petrol have been gone up. Still, firewood remains an exception. Although the relative importance of firewood had gone down, the actual and direct energy usage in absolute terms has gone up. It reflects the crude picture of the Indian economy – how desperately an Indian household remains dependent on firewood.

4.5. Direct Energy Usage across Settlement Categories

The firewood consumption has increased basically due to its increasing usage in rural areas. In town and city, direct energy consumptions from firewood have been declined significantly, but it has increased in the rural area – from 269 MJ to 308 MJ monthly per capita per, in 18 years.

On the other hand, consumption of dunk cake as a source of energy at the household level had increased for rural households. The decline is most for towns and is least for cities. The coal consumption is very lower than other major sources and the change of coal consumption during the study period is also low. One point to be noted here that the coal consumption was highest in towns and remains at the highest level, even if there was a decline in per capita coal consumption, overall in India.

During the study period, the use of LPG has spread to the rural area also. However, the actual consumption is still much lower, about 18.29 MJ monthly per capita in 2011-12, than that of towns and cities. The LPG usage has been increased to almost

87.87 MJ monthly per capita and 104.88 MJ monthly per capita, respectively for towns and cities.

Table 4.1: Monthly Per Capita Direct Energy Usage (MJ) across Settlement Categories in 1993-94 and 2011-12

Energy Items	1993-94				2011-12			
	Rural	Town	City	Total	Rural	Town	City	Total
Coke	3.05	8.07	2.98	**4.03**	1.70	3.76	1.17	**2.11**
Firewood	269.39	114.48	23.18	**226.18**	308.50	92.06	13.67	**241.13**
Electricity	8.18	29.31	55.12	**14.78**	32.85	87.18	122.47	**50.86**
Dung Cake	37.49	12.66	2.76	**30.81**	47.50	9.75	5.67	**36.42**
Kerosene	25.00	46.79	72.56	**31.76**	19.69	14.95	14.93	**18.34**
Coal	4.01	19.70	5.58	**7.16**	5.24	10.89	1.80	**6.22**
LPG	2.13	34.92	66.63	**11.93**	18.29	87.87	104.88	**39.37**
Charcoal	0.27	1.39	0.16	**0.48**	0.30	0.54	0.09	**0.34**
Candle	0.12	0.30	0.34	**0.16**	0.46	0.80	0.80	**0.56**
Gas	0.24	0.30	0.23	**0.25**	0.29	0.02	0.00	**0.21**
Petrol	1.39	8.77	25.14	**4.08**	11.49	39.11	59.20	**20.80**
Diesel	0.25	0.37	0.79	**0.30**	1.82	4.85	10.63	**3.10**
Other Fuels	1.36	0.92	0.57	**1.23**	0.73	0.40	0.57	**0.65**
Lubricants	0.02	0.12	0.19	**0.05**	0.08	0.30	0.40	**0.15**
All Energy	**352.89**	**278.08**	**256.22**	**333.2**	**448.95**	**352.47**	**336.27**	**420.24**

Source: Author's calculation
Note: MJ stands for Megajoules.

Petrol and Diesel are the two sources of energy, mainly used for private transportation, whose uses had increased many times across all the three settlement categories. However, the actual consumption level is lower for diesel than that of petrol across the settlement categories. And one notable point is that the per capita petrol consumption is much higher in towns (39 MJ monthly per capita in 2011-12) and cities (59.2 MJ monthly per capita in 2011-12) than in rural area (11.48 MJ monthly per capita in 2011-12) throughout the periods.

India's rural households traditionally consume the traditional sources of energy. From Table 4.1, it is clear that in 1993-94, rural households used mainly firewood, dung cake and kerosene. The modern sources of energy like electricity and LPG were almost absent or very insignificant in comparison to the traditional sources. The issues of non-accessibility and non-affordability of modern sources of energy were behind this low consumption level of modern energy in an average Indian household in 1993-94.

However, the monthly per capita energy consumption was more due to the firewood consumptions at a large scale. The scenario is different in 2011-12. Electricity, LPG and petrol consumption have increased substantially in rural area, however, not giving up the traditional sources. The consumption of traditional sources still remains at high level. The consumption of energy at town households are slightly different than rural households. The households in towns used to consume more coal, electricity, LPG and kerosene and less firewood and dung cake than that of rural households in 1993-94. And these patterns had changed further towards more modern sources of energy in 2011-12. And in cities, even in 1993-94, the major sources of energy at households were electricity, LPG and petrol as it is in 2011-12.

4.6. Direct Energy Usage across Income Classes

The variations of per capita direct energy use across different income classes have been captured in this section. Income is the major factor for determining the level of energy consumption at the household level. The principles of energy transition state that as the income of the households rises, households would go for more sophisticated or modern sources of energy like electricity and LPG by giving up the traditional sources like firewood, dunk cake, and coal. In a cross-sectional analysis, it can be said that households from higher-income classes (HIC) will spend proportionately more on modern sources of energy than average households from middle-income classes (MIC) and lower-income classes (LIC).

Table 4.2: Monthly Per Capita Direct Energy Usage (MJ) across Income Classes in 1993-94 and 2011-12

Energy Items	1993-94				2011-12			
	HIC	MIC	LIC	Total	HIC	MIC	LIC	Total
Coke	4.91	4.12	2.83	**4.03**	0.74	2.04	3.80	**2.11**
Firewood	275.43	222.52	187.36	**226.18**	221.74	250.82	232.61	**241.13**
Electricity	33.95	12.04	3.85	**14.78**	105.38	42.48	17.38	**50.86**
Dung Cake	38.70	30.27	24.46	**30.81**	35.33	36.78	36.52	**36.42**
Kerosene	39.89	32.54	20.96	**31.76**	15.72	19.48	17.69	**18.34**
Coal	7.45	7.68	5.18	**7.16**	2.89	6.49	8.98	**6.22**
LPG	32.68	8.73	0.85	**11.93**	82.51	34.01	9.01	**39.37**
Charcoal	0.76	0.51	0.11	**0.48**	0.36	0.40	0.12	**0.34**
Candle	0.41	0.12	0.04	**0.16**	0.90	0.54	0.26	**0.56**
Gas	0.73	0.16	0.06	**0.25**	0.73	0.09	0.01	**0.21**
Petrol	16.01	1.51	0.03	**4.08**	66.29	11.09	1.11	**20.8**
Diesel	1.23	0.09	0.003	**0.30**	11.83	0.91	0.29	**3.10**
Other Fuels	1.22	1.27	1.14	**1.23**	0.75	0.64	0.56	**0.65**
Lubricants	0.18	0.02	0.00	**0.05**	0.51	0.07	0.01	**0.15**
All Energy	**453.54**	**321.58**	**246.87**	**333.2**	**545.68**	**405.84**	**328.34**	**420.24**

Source: Author's calculation
Note: MJ stands for Megajoules;
LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.

It can be seen from Table 4.2, that the proposition of energy transition is true for firewood for both periods. The percentage shares of firewood out of total direct energy consumption is higher for LIC (187 MJ and 232.61 MJ) and subsequently lower for MIC (222.52 MJ and 250.82 MJ) and HIC (275.43 MJ and 221.74) for 1993-94 and 2011-12, respectively. The second highest is for HIC with 275 MJ monthly per capita in 1993-94, but declined to 221.74 MJ monthly per capita in 2011-12. And for LIC, the monthly per capita firewood consumption has increased from 187 MJ monthly per capita in 1993-94 to 232 MJ monthly per capita in 2011-12.

The energy consumption from coal was relatively lower than other traditional sources across all income classes. The monthly per capita energy consumption from coal has been declined for HIC and MIC but increased for LIC over the study period. This large decline in coal consumption for HIC is replaced mainly by the large increase in LPG consumption.

The monthly per capita LPG consumption for HIC has increased from 32.6 MJ in 1993-94 to 82.51 MJ in 2011-12. For MIC and LIC, monthly per capita LPG consumption also increased significantly, over the study periods. However, the actual energy consumption from LPG is much lower than that of HIC. The direct energy consumption from electricity is getting larger importance in all the income classes, and consumption for electricity is highest for HIC (33.95 MJ in 1993-94 and 105.38 in 2011-12) and lowest for LIC (3.85 MJ in 1993-94 and 17.38 MJ in 2011-12). For petrol and diesel, the levels of monthly per capita energy consumption were much higher for HIC and the difference became wider from MIC and MIC in 2011-12.

The energy consumption directly at household level was more for higher-income classes than others in 1993-94, and it remained even higher in 2011-12. The affordability issue is a concern here. Table 4.2 shows that the firewood consumption for HIC households were more than others in both the periods. By combining the Tables 4.1 and 4.2, it can be said that the higher level of energy consumption for HIC households is mainly because of higher level of firewood consumption by the rural HIC households.

Similar explanation can be applied for dung cake. It is the rural-HIC households, for which the tradition energy consumption is high for an average higher-income household. The consumptions of modern energy sources are also high in HIC households for both periods. The consumption of every energy sources of MIC households are more than LIC households, and that of HIC households are more than MIC households in both the periods. The positive income effects on consumption is clearly visible from the Table 4.2.

4.7. Direct Energy-related CO_2 Emission across Settlement Categories

Contrary to direct energy consumption, monthly per capita CO_2 emission (energy-related) has declined for most of the sources of energy. Firewood, LPG, petrol, and diesel are the few exceptions in it. The consumption level has increased for the last three sources, due to natural choice as a modern sources of energy. But, a traditional source like firewood has got increased its consumption, and also have increased CO_2 emission (25.33 Kg CO_2 monthly per capita in 1993-94 to 27 Kg CO_2 monthly per capita in 2011-12).

However, the overall emission from an average household has increased from about 33 Kg of CO_2 monthly per capita in 1993-94 to about 37 Kg of CO_2 monthly per capita in 2011-12. Only in the rural area where there is an increasing level of CO_2 emission (30 Kg CO_2 monthly per capita in 1993-94 to more than 43 Kg CO_2 monthly per capita).

Among the other sources of energy, coal remains an important polluting source of energy in towns, not in cities or rural areas; it contributed 8 per cent of total energy-related CO_2 emission in 1993-94 and it is still at 4.82 per cent of total energy-related CO_2 emission in 2011-12. The coke, charcoal, candle, gas, diesel, other fuels, and lubricants remain minor contributors in CO_2 emission in an average Indian household still in 2011-12, irrespective of the settlement types.

Table 4.3 - Monthly Per Capita Direct CO2 Emission (Kg) across Settlement Categories in 1993-94 and 2011-12								
Energy Items	**1993-94**				**2011-12**			
	Rural	**Town**	**City**	**Total**	**Rural**	**Town**	**City**	**Total**
Coke	0.33	0.87	0.32	**0.44**	0.18	0.40	0.13	**0.23**
Firewood	30.17	12.82	2.60	**25.33**	34.55	10.31	1.53	**27.01**
Dung Cake	3.75	1.27	0.28	**3.08**	4.75	0.97	0.57	**3.64**
Kerosene	1.80	3.36	5.22	**2.28**	1.42	1.08	1.07	**1.32**
Coal	0.38	1.86	0.53	**0.68**	0.50	1.03	0.17	**0.59**
LPG	0.13	2.20	4.20	**0.75**	1.15	5.55	6.62	**2.48**
Charcoal	0.03	0.16	0.02	**0.05**	0.03	0.06	0.01	**0.04**
Candle	0.01	0.02	0.03	**0.01**	0.03	0.06	0.06	**0.04**
Gas	0.01	0.01	0.01	**0.01**	0.02	0.00	0.00	**0.01**
Petrol	0.10	0.61	1.74	**0.28**	0.80	2.71	4.10	**1.44**
Diesel	0.02	0.03	0.06	**0.02**	0.14	0.36	0.79	**0.23**
Other Fuels	0.10	0.07	0.04	**0.10**	0.06	0.03	0.04	**0.05**
Lubricants	0.00	0.01	0.01	**0.00**	0.01	0.02	0.03	**0.01**
All Energy	**36.83**	**23.29**	**15.05**	**33.04**	**43.63**	**22.58**	**15.12**	**37.09**
Source: Author's calculation								

It can be observed from Table 4.3 that the CO_2 emission were more in rural households than an average household in towns and cities, and that is extremely due to large dependency of rural households on the firewood for energy. Another significant polluting source was dung cake. This tradition continues in 2011-12 also, specifically CO_2 emission due to firewood and dung cake have been increased further. The CO_2 emission in towns and cities are much lower than that of rural households. It is due to very less firewood consumption in towns and cities. However, there is an increasing trend for consumption of LPG and petrol in towns and cities, hence the CO_2 emissions are also increasing for them in towns and cities.

4.8. Direct Energy-related CO2 Emission: across Income Classes

There is a variation of CO_2 emission by various sources of energy also across different income classes. The energy-related CO_2 emissions of various sources of energy in the rural areas are mainly by the lower-income classes. The pattern remains, more or less, the same in 2011-12 as it was in 1993-94 in LIC. It is about 84.6 per cent of total CO_2 emission (26 Kg of CO_2 monthly per capita) from firewood combustion in 2009-10 which is a bit higher than the figure from 1993-94 (about 21 Kg of CO_2 monthly per capita), in an average lower-income class household.

Table 4.4 - Monthly Per Capita Direct CO_2 Emission (Kg) across Income Classes in 1993-93 and 2011-12

Energy Items	1993-94				2011-12			
	HIC	MIC	LIC	All India	HIC	MIC	LIC	All India
Coke	0.53	0.45	0.31	**0.44**	0.08	0.22	0.41	**0.23**
Firewood	30.85	24.92	20.98	**25.33**	24.84	28.09	26.05	**27.01**
Dung Cake	3.87	3.03	2.45	**3.08**	3.53	3.68	3.65	**3.64**
Kerosene	2.87	2.34	1.51	**2.28**	1.13	1.40	1.27	**1.32**
Coal	0.71	0.73	0.49	**0.68**	0.27	0.61	0.85	**0.59**
LPG	2.06	0.55	0.05	**0.75**	5.21	2.15	0.57	**2.48**
Charcoal	0.09	0.06	0.01	**0.05**	0.04	0.05	0.01	**0.04**
Candle	0.03	0.01	0.00	**0.01**	0.07	0.04	0.02	**0.04**
Gas	0.04	0.01	0.00	**0.01**	0.04	0.01	0.00	**0.01**
Petrol	1.11	0.11	0.00	**0.28**	4.59	0.77	0.08	**1.44**
Diesel	0.09	0.01	0.00	**0.02**	0.88	0.07	0.02	**0.23**
Other Fuels	0.09	0.10	0.09	**0.10**	0.06	0.05	0.04	**0.05**
Lubricants	0.01	0.00	0.00	**0.00**	0.04	0.01	0.00	**0.01**
All Energy	**42.34**	**32.29**	**25.89**	**33.04**	**40.77**	**37.13**	**32.98**	**37.09**

Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.

The consumption of dunk cake and kerosene is significant during the study period in LIC households. A significant share of duck cake and kerosene still a part of LIC households. For a middle-income household – increasing consumption of firewood, and declining consumptions of dunk cake and kerosene had been observed for energy-related CO_2 emission. However, the pattern is somehow different in an average higher-income household. Unlike MIC or LIC, the contribution of firewood in CO_2 emission has gone down in HIC, from 30.848 Kg in 1993-94 to 24.35 Kg in 2010-11 over the study period.

The CO_2 emission in HIC households were more than any other households in 1993-94. This was mainly the over dependency of firewood and dung cake of Rural-HIC households in India. About a three-fourth of the total CO_2 emission in HIC households just due to firewood alone. The CO_2 emission level has come down slightly for HIC households over the periods 1993-94 to 2011-12. The that emission for firewood is now just more than half of the total emission in 2011-12 by an average HIC households. The place is captured by the increasing emission due to LPG and petrol. Similar picture can be obtained for MIC households; but the emission from firewood is more in MIC than that of HIC in 2011-12. The emission from firewood consumption had increased at LIC household significantly.

On the whole, it can be inferred from the analysis that firewood is still the predominant source of energy in Indian households. Despite the rapid increase in the usages of modern and sophisticated sources of energy, firewood still remains in a top position, mainly in rural areas and towns. On the other hand, the modern sources of energy like electricity and LPG are gaining their space in almost every category of households between 1993-94 and 2011-12. It is important to note here that coal, dung cake, and kerosene are the major losers – losing the ground as sources of energy in Indian households.

An analysis across settlement categories has revealed that monthly per capita consumption of firewood has rapidly declined for town and city, but it has increased in the households of rural areas. A similar type of behaviour has been observed for coal consumption. On the other hand, firewood and coal-related CO_2 emissions are also having similar outcomes. Dung cake consumption has declined for all types of households in rural, town, and city and their corresponding CO_2 emission also.

The direct energy requirement and direct energy-related CO_2 emission are providing a partial picture of the whole scenario. The energy consumed by a household through the consumption of different goods and services. The non-energy items consumed by a household contain some embodied energy in the process of their production. The households are consuming that energy also indirectly. Therefore, to account for the total energy consumed by a household, one must consider that indirect energy is embodied in the goods and services which are consumed by those households. Therefore, the total energy consumed by the household sector, directly and indirectly, is more than what one sees. The same logic is an application to energy-related CO_2 emission also. A certain amount of CO_2 would be released into the atmosphere to produce goods and services. Therefore, for calculating the CO_2 emission associated with the total energy consumption at the household level, one must consider the CO_2 emission indirectly in the production sectors.

This chapter helped us to understand the direct energy consumption and related CO_2 emission at Indian households. The differential direct energy consumption patterns and CO_2 emission patterns can also be obtained across different income classes and settlement categories over the periods 1993-94 to 2011-12. This analysis helps us to understand and measure the total energy consumption, directly and indirectly, in chapter 5. The chapter 5 would deal the total energy consumed by the households, firstly, by using energy sources directly at households and secondly, the energy consumption indirectly by consuming every consumption item at the households. To produce every item, a certain amount of energy is used at production sector. The previous, chapter (Chapter 3) has measured the energy intensity inside every good produced in the economy. By using the results from this chapter and chapter 3, the Chapter 5 would measure the total energy consumption by households. Similarly, the findings of CO_2 emission due to direct energy uses are also be used in Chapter 5 to measure the total CO_2 emission at household level.

Chapter - 5

Total Energy Use and related CO_2 Emission

5.1. Background

Since the 1970s, researchers had started investigating the households' direct and indirect energy requirements. To assess the direct and indirect energy use at household level in USA, Herendeen and Tanaka (1976) had combined the household consumption expenditure data with the results of energy input-output analysis. They analysed various factors that influence energy consumptions. The household characteristics such as consumption expenditure, household size, and the level of urbanization were found to be the major factors. Around one-third to two-third of total energy requirements at households came from indirect energy consumption. It shows the importance of indirect energy in USA households. Similar results were found from other studies on other countries, which included Australia (Lenzen et al., 2004), Brazil (Cohen et al., 2005), India (Pachauri, 2004), Norway (Herendeen, 1978), New Zealand (Peet et al., 1985) and The Netherlands (Vringer and Blok, 1995; Biesiot and Noorman, 1999).

From these studies on household energy consumption, it can be said that households consume energy directly when the households use energy sources directly at household level; the household also consume energy indirectly when the household uses non-energy goods and services. The energy embodied within the non-energy goods and services are also consumed by the households as ultimate consumers. A large number of researchers working on energy economics attempted to emphasis on factors which are related to the structure of the economy for the longer-term. The structural change of the economy has immense importance on shaping the consumption patterns. The change in long term volume and composition of the consumption could be termed as the long-term lifestyle effect. A person's lifestyle can be captured by observing the expenditure patterns of the households (Perrels et al., 1995). In turn, these patterns are on the one hand influenced by broad societal and technical changes and on the other hand, the expenditure patterns predetermine to a significant extent the required type and amounts of energy (Weber and Parrels, 2000).

The present chapter focuses on the total energy requirements, direct and indirect energy demand at the household level. A household consumes not only direct energy at household level, but the indirect energy also, while consuming other goods are services. Because, to produce every goods and services a certain amount of energy got embodied with the goods (Kerkhof et al., 2009b). Through its various production sectors intermediate goods pass that energy embodied in inputs to another sectors. Ultimately, it comes to households for final consumption. Therefore, when a household consumes any final goods, it consumes some energy embodied within that goods through the production chain. This chapter also focuses on measurements of total energy requirement comprising direct energy and indirect energy, across the different income classes and across different settlement categories in India over the periods 1993-94 to 2011-12. The similar investigation will be done for the energy-related total CO_2 emissions, together direct and indirect CO_2 emissions (Kerkhof et al., 2009b). This chapter focuses not only on aggregated level, but at different consumption bundle level also. This will help to identify the specific consumption bundle for which the overall energy consumption is increasing or decreasing. Similar exercises would be done for all consumption bundles for measuring total CO_2 emissions at household level.

5.2. Sources of Data

Two data sources are used for the analysis in this chapter. One is related to information of household consumption at disaggregated level– item-wise. The NSSO provides robust information on household consumption almost of all consumption items from a large number of households all over India from different income classes. The household consumption data for 1993-94 and 2011-12 has been considered to match with the input-output models of this chapter.

Consumer price indices are also used to make that consumption expenditure at a constant price. Here, in this study, all the monetary value of consumption has been converted into a 1993-94 price level. Moreover, a large gap between the two consumption data sets provides sufficient information about the change of the consumption pattern among the households.

Along with the household consumption data, information on energy and environmental input-output models are also required. The methodological issues have been discussed in Chapter three[26]. The CSO input-output transactions tables for the years,

[26] In chapter three, the energy intensity and the related CO_2 emission intensity of aggregated sectors of Indian economy have been calculated by using the hybrid energy input-output analysis. The intensity

1993-94 and 2007-08 have been used. As there is no updated input-output table available so far, then this study has to base on the two only. A large gap between these two tables would give a good sense of structural changes in the sectors of the Indian economy during these two periods. The wholesale price index, energy statistics, and the energy conversion factors and energy-related CO_2 emission factors have been used to calculate the sectoral energy intensity and energy-related CO_2 emission intensity for both periods. This exercise has been done in the previous chapter, chapter 4, and the information on calculated energy intensity and energy-related CO_2 emission intensity has been used in this chapter.

5.3. Analytical Framework

This chapter relies on the input-output framework and uses similar technique applied in the fourth chapter. The total energy intensity and the energy-related CO_2 emission intensity have been calculated by applying the extension of Leontief's input-output framework for the periods of 1993-94 and 2007-08. Thus calculated intensity has been used in this chapter in combination with information on household consumption items for both periods. The direct energy embodied in any consumption items has been calculated first, and then the embodied energy-related CO_2 emission also. This method of energy input-output will help to calculate the total energy consumed (directly and indirectly) by any households while consuming goods and services. Similarly, the households' total emission level (CO_2 only) for the consumption of energy and non-energy goods and services.

calculated there are used in this chapter to find out the indirect energy consumptions by the households while consuming other goods and services.

By assuming the major material competent of any household consumption item, the concordance has been done between the input-output sectors and the households' consumption – consumption item-wise. The energy (total) intensity of that input-output sector has been linked with the corresponding household consumption items to find out the embodied energy requirements of all goods and services consumed at the household level.

Now, it assumed that S_i is the monthly per capita household consumption of i^{th} item. Therefore, total energy consumed, directly and indirectly, by the households by consuming that item, monthly per capita basis, can be obtained as: $(S_i * \propto_i)$, where $\propto_i$ is the energy intensity. Some consumption items are clubbed into a small number of consumption bundles, say j. Hence, total energy consumed by the households for the j^{th} consumption bundle, on a monthly per capita basis, can be represented as: $\sum_{i=1}^{i} S_i \propto_i$. By summing up all the consumption bundles, the total energy consumed by the households, on a monthly per capita basis, can be obtained. By adding the energy requirement for all the consumption bundles, the total energy can be measured on a monthly per capita basis. Similarly, that can be measured for two-income classes, and three settlement categories separately.

Similarly, to calculate the environmental impact (total) of the household consumption, one needs to combine the energy-related CO_2 emission intensity from the environmental input-output analysis with the information of the household consumption. In chapter 4, the direct energy use and its related CO_2 emissions have been calculated. And in chapter 3, the energy use and its related CO_2 emission for aggregated sectors of Indian economy have been calculated. Then energy embodied and CO_2 emission calculated in chapter 4 will be used to calculate the energy consumption indirectly by consuming non-energy goods at Indian households.

In this chapter, the total energy consumption and related CO_2 emission will be calculated by considering to direct consumption and indirect consumption by the households. The environmental impact, only through the energy-related CO_2 emission, resulted from the household consumptions has been measured quantitatively for each household on a monthly per capita basis. Analysis has also been carried out by household clusters.

Depending upon the similarity of the consumption patterns of the households in 1993-94, all households in India are grouped into four household clusters. Cluster A consists of all the lower-income households in rural areas (Rural-LIC) only. Cluster B consists of all the middle-income households in rural areas (Rural-MIC) and all the lower-come households in towns and cities (Town-LIC and City-LIC, respectively). All the higher-income households in rural areas (Rural-HIC) and all the middle-income households in towns and cities (Town-MIC and City-MIC, respectively) are in household Cluster C. And lastly, the household Cluster D consists of all the higher-income households in towns and cities (Town-HIC and City-HIC, respectively).

5.4. Calculation of Total energy and CO_2 Emission

5.4.1. Changes in Monthly per Capita Energy Consumption

The energy consumed at the household level is measured by the energy unit Million Joule or Mega Joule (MJ). On average, an Indian household used 801.59 MJ of energy monthly per capita in 1993-94. However, the energy consumption has increased more than double (about 217 per cent increases) in 2011-12, which is about 2542 MJ (monthly per capita). However, the increase for non-energy items during the same period is less than double (86 per cent increase, only). On the other hand, the increase for energy items is about 317 per cent during the same period. Table 5.1 has documented the change of monthly per capita energy consumption at the household level in both periods. The presentation is based on two types of classification of households – settlement categories and income classes.

Table 5.1: Monthly Per Capita Energy Consumption (MJ) by Indian Households in Different Settlement Categories

	Rural	Town	City	HIC	MIC	LIC	All India
				1993-94			
Total: Non-Energy Items	295.23	460.56	642.96	699.20	290.85	158.86	345.84
Total: Energy Items	420.09	523.84	712.17	729.79	419.72	289.69	455.75
TEPC (MJ)	715.32	984.41	1355.13	1428.99	710.56	448.55	801.59
				2011-12			
Total: Non-Energy Items	535.23 *(81%)*	840.29 *(82%)*	1145.98 *(78%)*	1386.82 *(98%)*	507.44 *(74%)*	255.76 *(61%)*	643.94 *(86%)*
Total: Energy Items	1564.14 *(272%)*	2519.83 *(381%)*	3310.51 *(365%)*	3743.68 *(413%)*	1562.63 *(272%)*	925.25 *(219%)*	1898.61 *(317%)*
TEPC (MJ)	2099.36 *(193%)*	3360.13 *(241%)*	4456.49 *(229%)*	5130.49 *(259%)*	2070.07 *(191%)*	1181.01 *(163%)*	2542.55 *(217%)*

Source: Author's calculation
Note: The figures in the parentheses are showing the percentage changes over its value from 1993-94.
HIC, MIC, LIC stand for Higher Income Class, Middle Income Class, and Lower Income Class, respectively.
MJ stands for Million Joule (Mega Joule);
TEPC stands for per capita total energy.

In fact, for both the classifications, the monthly per capita household energy consumption (total) has been increased for all income classes and all types of settlement categories. And there is a positive increase in monthly per capita energy consumption for energy items, non-energy items, and total, of course. Among the three types of income classes, the increase is maximum for the higher income class (259 per cent) followed by the middle-income class (191 per cent) and lower-income class (163 per cent). An increase in energy consumption due to energy items is more than that of non-energy items for all the income classes. However, that increase for energy items is most (413 per cent) for higher-income class households. on the other side; energy consumption has been increased for all types of settlement categories.

5.4.2. Changes in Monthly Per Capita CO2 Emission

A similar exercise has been done for energy-related CO_2 emissions. As it has been shown in the last section that monthly per capita energy consumption increased for almost every type of household in India during the period 1993-94 to 2011-12. However, the monthly per capita CO_2 emission has mixed results during the same periods. The monthly per capita CO_2 emission has been increased by 18 per cent; from 60.28 kg in 1993-94 to 71.10 kg in 2011-12. In energy items, it is increased by 43 per cent over the period. And that is for the non-energy sector has been gone down by 20 per cent over the same period.

Table 5.2: Monthly Per Capita CO2 Emission (Kg) by Indian Households in different Settlement Categories

	Rural	Town	City	HIC	MIC	LIC	All India
				1993-94			
Total: Non-Energy Items	20.48	30.35	43.07	45.063	20.56	11.26	23.60
Total: Energy Items	38.91	30.18	28.92	50.47	35.29	26.98	36.68
CO2EPC (Kg)	59.39	60.53	71.99	95.53	55.85	38.24	60.28
				2011-12			
Total: Non-Energy Items	15.61 (-24%)	24.88 (-18%)	32.76 (-24%)	41.28 (-08%)	14.59 (-29%)	7.35 (-35%)	18.81 (-20%)
Total: Energy Items	57.42 (48%)	39.40 (31%)	39.61 (37%)	65.27 (29%)	51.01 (45%)	42.12 (56%)	52.28 (43%)
CO2EPC (Kg)	73.03 23%)	64.28 (06%)	72.37 (-01%)	106.55 (12%)	65.60 (17%)	49.47 (29%)	71.10 (18%)

Source: Author's calculation
Note: The figures in the parentheses are showing the percentage changes over its value from 1993-94.
HIC, MIC, LIC stand for Higher, Middle, and Lower Income Classes, respectively.
CO2PC stands for per capita CO_2 Emissions.

For the in-depth knowledge about the movement of energy consumption and energy-related CO_2 emission within the energy items and non-energy items, one must need to investigate specific items-wise. All the consumption items at the household level have been grouped into a total of 21 categories depending upon the nature of the consumption items and the purpose of the use.

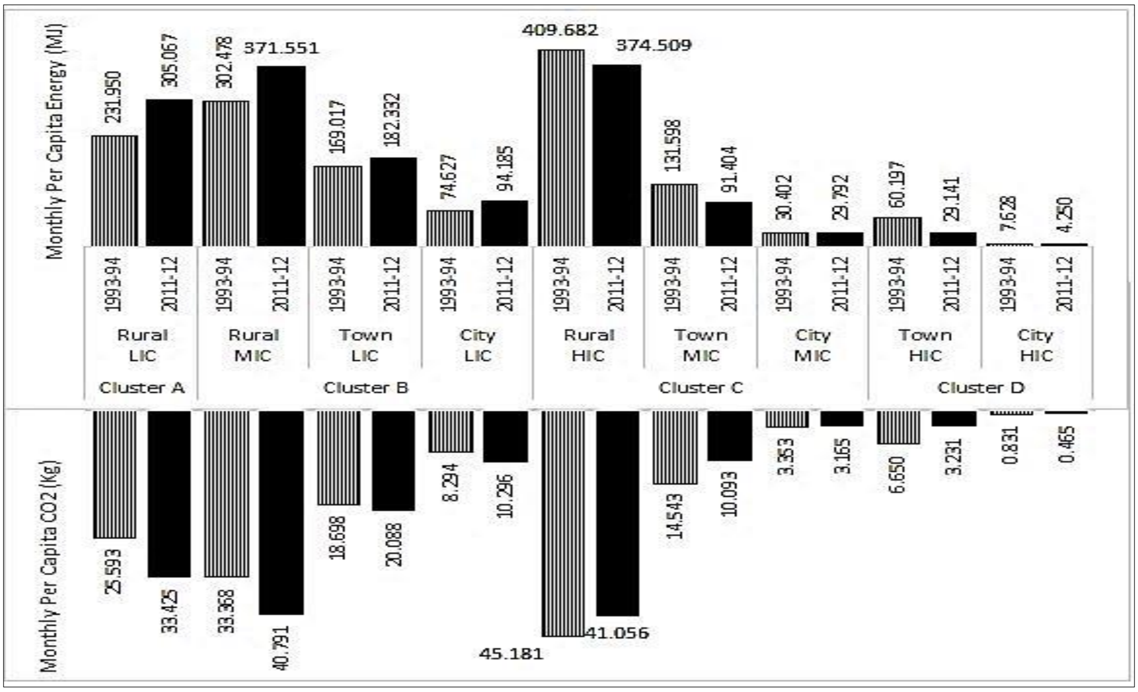
5.4.3. Energy Items Use by Different Households

a) Firewood and Dung Cake

The consumption of firewood and dung cake is not uniform among the different types of households. The energy consumption from firewood and dung cake was at a very high level in 1993-94 in the rural area irrespective of the income classes and even it became higher in 2011-12. The energy consumption from firewood and dung cake was at the highest level for higher-income class households in the rural area and still is at the higher level in 2011-12 (see Figure 5.1). The monthly per capita energy consumption from firewood and dung cake was about 410 MJ in 1993-94 for higher income class households in the rural area. In 2011-12, it remained the highest among all other household classes with 374 MJ monthly per capita, a slightly lower than 1993-94.

Over the same time, the monthly per capita energy consumption from firewood and dung cake of middle-income class households in rural areas caught the level of that of higher-income class households in rural in 2011-12, with 371 MJ monthly per capita. Among the other household types, lower and middle-income households in towns also have moderately increased energy consumption. The households under cluster D and the middle-income class households in the city are having decreasing energy consumption from firewood and dunk cake. Overall, energy consumption through firewood and dung cake is mainly a rural phenomenon.

Figure 5.1: Firewood & Dung Cake:
Monthly Per Capita Energy and CO_2 Emissions in 1993-94 and 2011-12



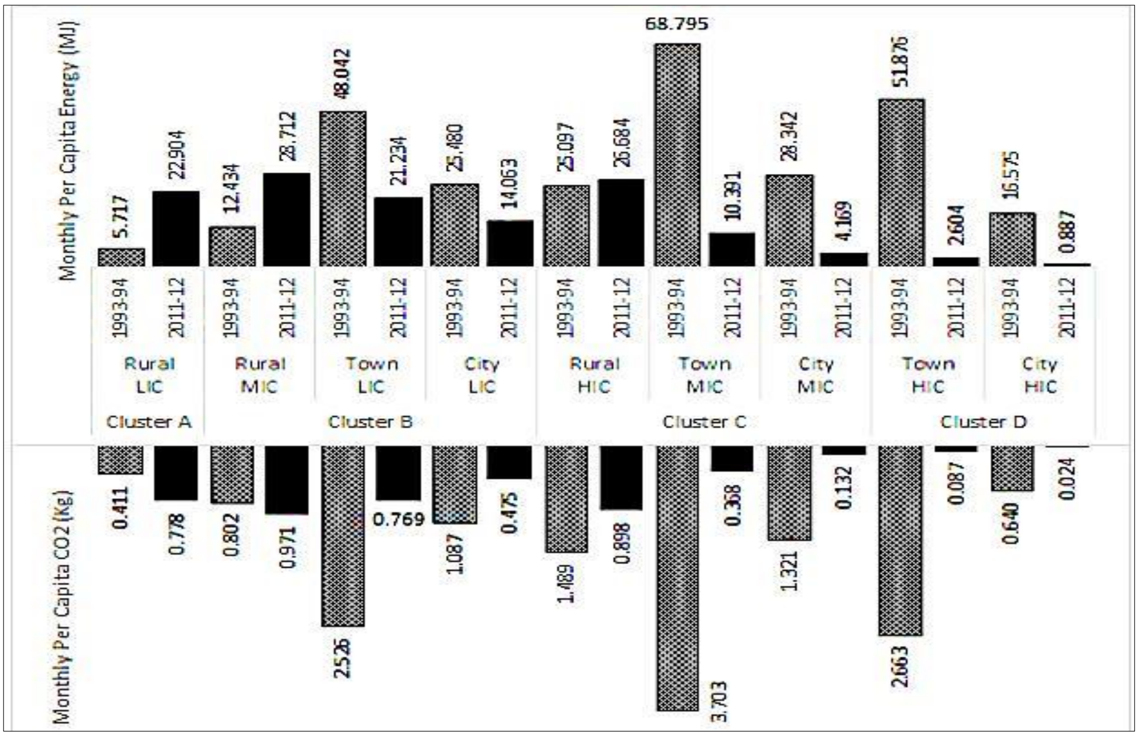
Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

Similar to the monthly per capita energy consumption, the energy-related CO_2 emission from firewood and dung cake combustion are having the same pattern among the different types of households. All types of rural households are consuming more energy from firewood and dung cake and hence energy-related CO_2 emission from firewood is also much higher in those households in the rural area. The affluent households (HIC) in the rural area are emitting about 41 Kg of CO_2 (monthly per capita) in 2011-12 which is comparatively lower than 45 Kg of CO_2 emission in 1993-94. The energy consumption and related CO_2 emission from firewood and dung cake are much lower in the urban area, mainly in big cities. This is mainly due to the non-availability of firewood in the urban area.

b) Coal & Coke

As firewood and dung cake consumption is mostly a rural phenomenon, the consumption of coal and coke is mostly a town phenomenon. In 1993-94, the urban areas, specifically towns, were the major user of coal and coke. The monthly per capita energy consumption and related CO_2 emission were high in all types of households in towns. However, over 18 years, the rural areas are using more energy from coal than towns. For example, in 1993-94, the middle-income class households in town were using more energy on a per capita basis and related CO_2 emission. Whereas, in 2011-12, it is rural middle-income class (MIC) households which took lead in monthly per capita coal and coke consumption in energy term. All households in cluster D and cluster C (except, rural HIC), energy consumption from coal and coke are not so significant, and hence CO_2 emissions in 2011.

Figure 5.2: Coal & Coke:
Monthly Per Capita Energy and CO_2 Emission in 1993-94 and 2011-12



Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

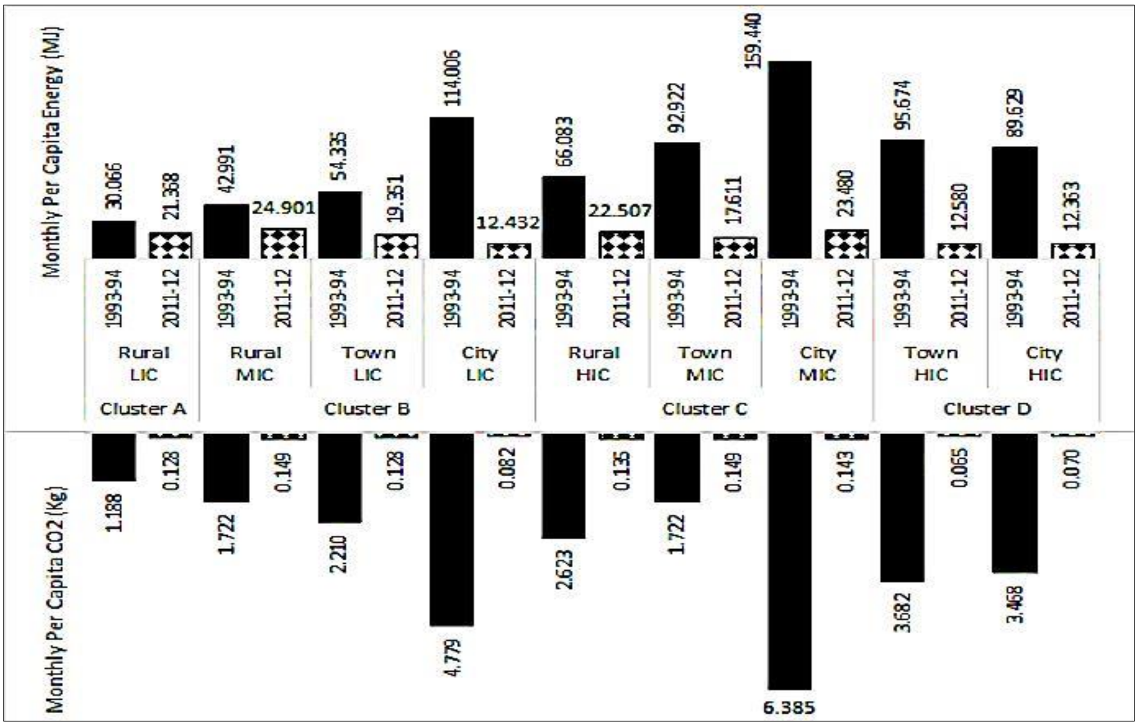
c) Kerosene

The energy consumption from kerosene has changed enormously during the study periods. Although the monthly per capita energy consumption has increased many times for all the types of households during the study period, but it is not uniform for all household types. There is a massive change in the scenario. Now, the rural households are also consuming energy from kerosene, equally with the other households in town in 2011. The rural HIC households were consuming the lowest level (only 30.066 MJ monthly per capita) of energy from kerosene in 1993-94; it is now dropped to 21.368 MJ monthly per capita in 2011-12 (and not the lowest anymore). However, the largest drop is bagged by the city MIC households – 159.440 MJ to 23.480 MJ during the same period. MIC households in the city were the highest energy-consuming households in 1993-94, which is now the second-highest consumer. The highest energy-consuming households in 2011-12 are rural MIC households (24.901 MJ monthly per capita).

The highest jump for energy consumption from kerosene is for MIC households in the rural area by about 178 MJ monthly per capita. More or less, the energy consumption from kerosene is relatively lower in households in cluster D in both periods, and it still declined further in 2011-12. Similar to energy consumption, the energy-related CO_2 emission has declined almost for all types of households many times. In 1993-94, the highest emitters (6.385 Kg) were the MIC households in the city, and the second-highest emitters (4.779 Kg) were the LIC households in City. The other two larger emitters were the HIC households in towns and cities. So, overall the city households were the largest emitters in 1993-94. However, the emission levels have dropped to a significant level. For the HIC households in town and city, it is mainly due to a decline in the consumption level. The uses of electricity and LPG took the place of kerosene in the urban area.

Kerosene consumption was dropped in the urban area mainly due to increase consumption of electricity and LPG.

Figure 5.3: Kerosene:
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12

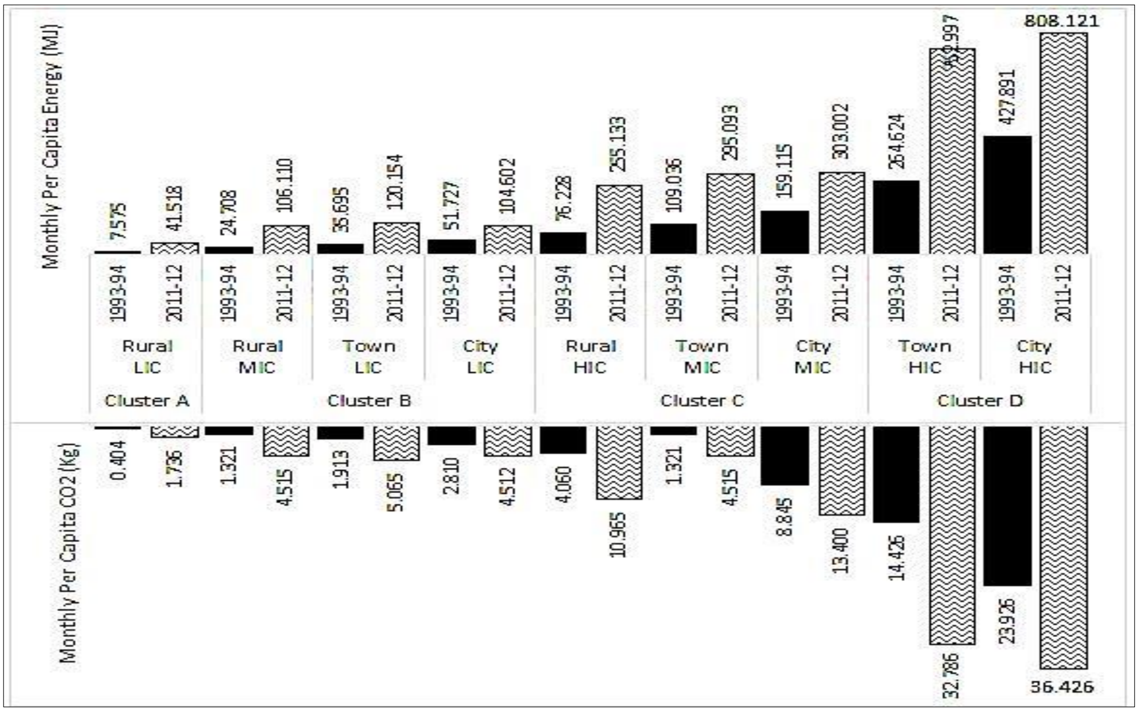


Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

d) Electricity

Energy consumptions from electricity is much skewed among the types of households as compared to other sources of energy. From Figure 5.4, it can be seen the highly skewed distribution of energy consumption from electricity in different types of households. The monthly per capita consumption level is extremely lower in households of clusters A and B. It is extremely high for the households in cluster D. whereas, it is moderately high for the households in cluster C. For example, the monthly per capita energy consumption was lowest at 7.575 MJ in 1993-94 in Rural LIC households (in cluster A), and still, it is at the lowest level of 41 MJ in 2011-12. On the other hand, the households in cluster D used a much higher level of energy (e.g., 427.891 Kg for HIC in the city) in 1993-94 and it remained at higher (808 MJ) in 2011-12. Although there was a rise in energy consumption in all household types over the study period, the rise is much more in households in the higher end (cluster D) than that of the lower end (towards cluster A). It is a complete and extreme example of divergence.

Figure 5.4: Electricity:
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



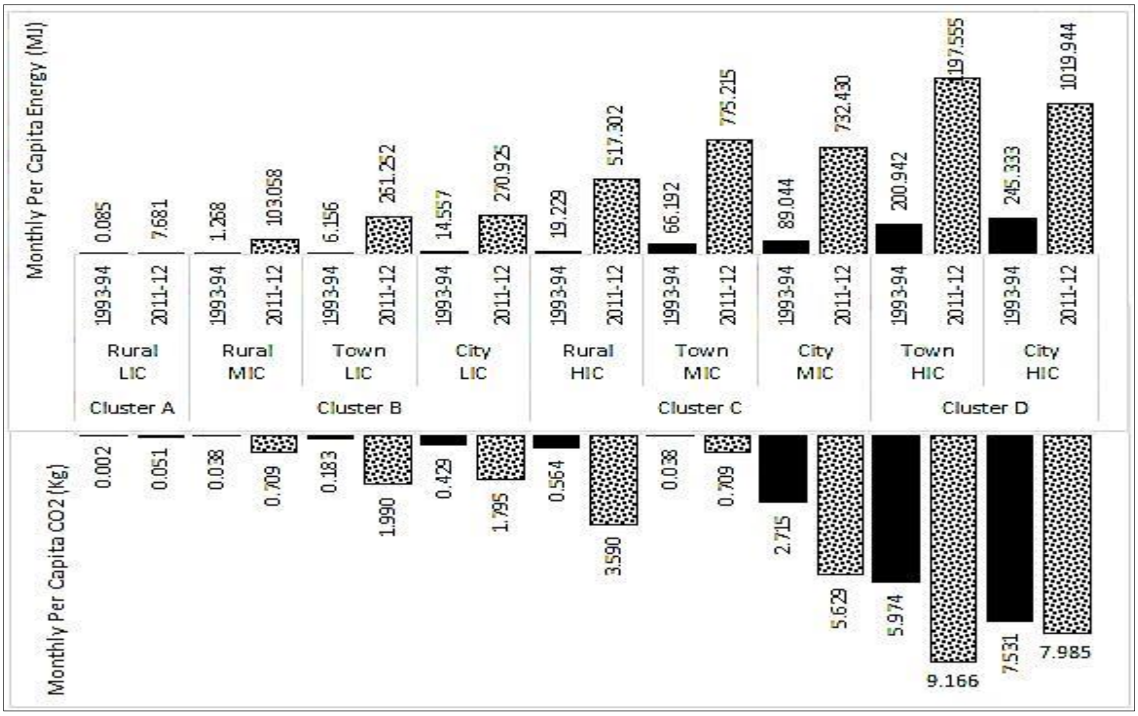
Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

The energy-related CO_2 emissions from electricity consumption across the different types of households have a similar scenario as in the case of electricity energy consumption. There was a huge difference in lower and higher ends of the consumption pattern structures (0.404 Kg for LIC in rural and 23.926 Kg for HIC in the city) in 1993-94. There was an increase in CO_2 emission from electricity consumption across all types of households from 1993-94 to 2011-12, and the increase is more in the higher end of the cluster. It is only by 1.3 Kg for LIC households in rural, whereas it is by about 18 Kg for HIC households in town.

e) LPG

The consumption pattern for LPG is almost similar to the electricity consumption pattern. It was a very low level at the lower end of the cluster and higher in the higher end of the cluster for both the periods (Figure 5.5). The situation is still diverging; the incremental measure was just about 2.48 MJ in cluster A, the about more than 700 MJ in cluster D (higher end).

Figure 5.5: LPG:
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

The energy consumption from LPG is in increasing trend as moving from cluster A to cluster D for both the period. Similar to energy consumption, the energy-related CO_2 emission is skewed towards the cluster D (the higher end). In comparison to the lower end, the households in higher ends (cluster D and MIC in the city in cluster C) emit LPG-related CO_2 emission many folds more, for both the periods.

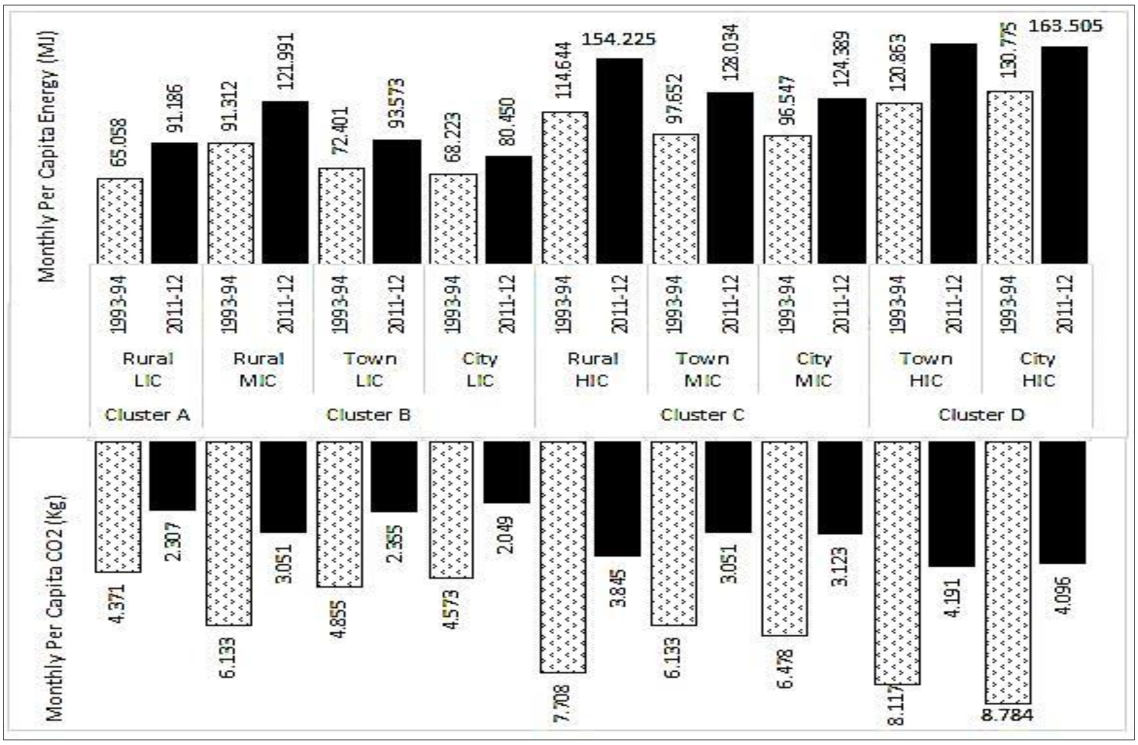
5.4.4. Food Items

Food items are very important components of household consumption. A large part of the total expenditure is going for the purchase of food items. The total food items have been aggregated into six consumption bundles viz., 1) cereals, pulses, and vegetables, 2) milk, eggs, fish, and meat, 3) fruits, 4) other foods (including spices), 5) beverages and processed foods, 6) pan, tobacco, and intoxicants. Generally, the pan, tobacco, and intoxicants are not considered as food items as they do have any nutritional values. However, as in this study, the nutritional value judgment was not the basis for consumption items classification, so the pan, tobacco, and intoxicants are considered as the edible items and included in food items with separate grouping. The other important point to be noted here that the fuels required for cooking these food items at households are also not considered here into these food consumption bundle as these are already considered into specific energy items.

f) Cereals, Pulses & Vegetables

Cereal is the major component of food irrespective of the class. And, cereals along with pulses and vegetables comprise most of the daily food consumption part. Although the energy consumptions from cereals, pulses, and vegetables are higher in the higher end of the consumption cluster, the lower end is also consuming a substantial level of energy for this food consumption bundle (Figure 5.6). And monthly per capita energy consumption has increased for all the types of households. The energy consumption is more in the case of higher-income class households. An increase in energy consumption due to cereal, pulses and vegetables are higher in those higher income class households.

Figure 5.6: Cereals, Pulses & Vegetables:
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



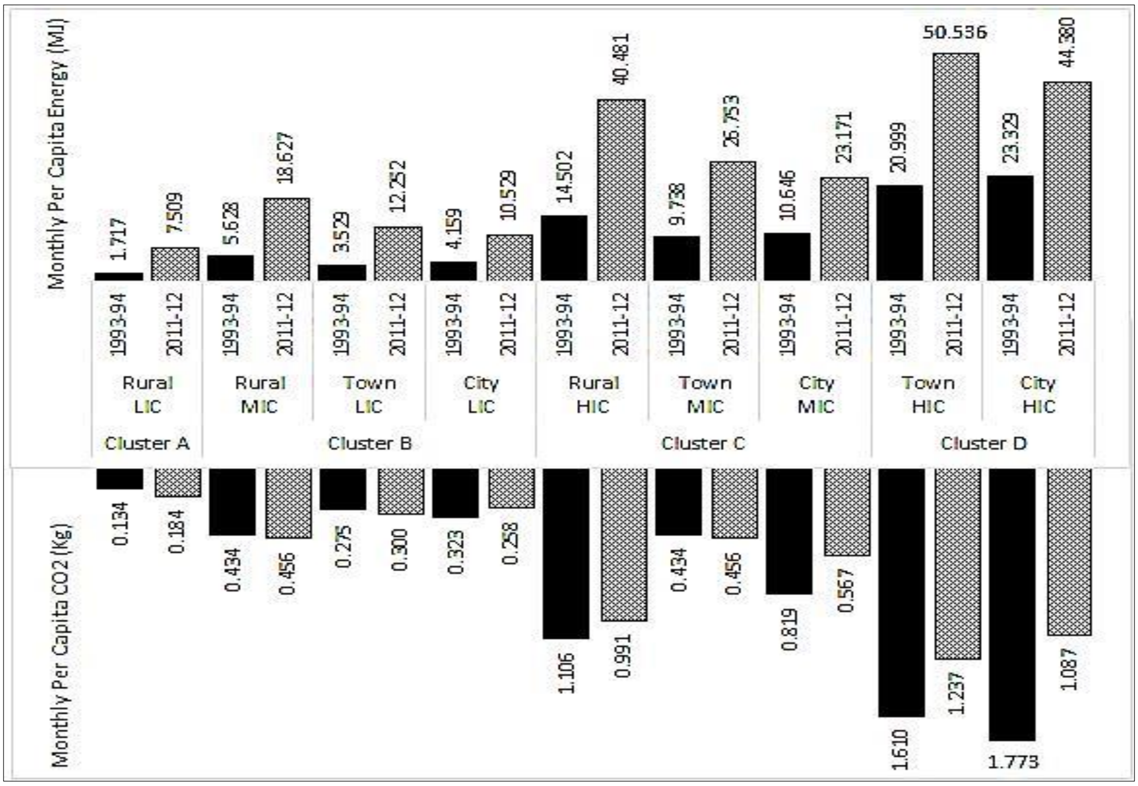
Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

The CO_2 emission due to consumption of cereals, pulses, and vegetables has declined by almost two folds for each type of household in the consumption cluster during the study period. The highest and lowest monthly per capita CO_2 emitters were HIC households in the city (8.784 Kg) and LIC households in the rural area (4.371 Kg) in 1993-94, respectively. Whereas, in 2011-12, the monthly per capita CO_2 emission declined significantly to 4 Kg for HIC city households and 2.3 Kg for LIC rural households. More or less, the pattern is the same in 2011-12 as it was in 1993-94. The only difference is that cereal and pulses related CO_2 emission have gone half for almost all types of households during the period.

g) *Milk, Egg, Fish & Meat*

These protein-based consumption items are another example of skewed distribution of energy consumption and related CO_2 emission among the different types of households. The households in clusters A and B are using a very low amount of per capita energy for these consumption items in 2011-12 as it was low in 1993-94.

Figure 5.7: Milk, Egg, Fish & Meat:
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

However, there is an increase in energy consumption levels for all sorts of households. For example, the energy consumption for LIC in rural households was 1.717 MJ monthly per capita in 1993-94 and it increased to only 7.006 MJ monthly per capita in 2011-12. On the other hand, the energy consumption from milk, egg, fish, and meat is much more in clusters C and D for both the periods and increased more than double the proportion during the same period. The highest energy consumption was 23.329 MJ in

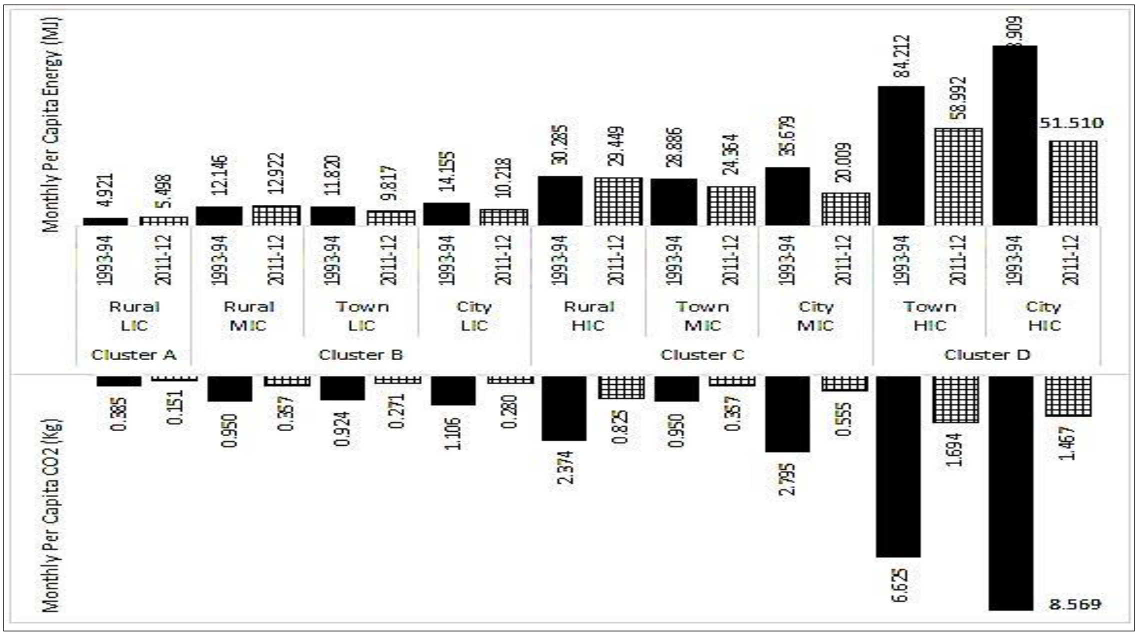
1993-94 for HIC households in the city and it increased further to 44 MJ in 2011-12. The highest changes can be observed in HIC households in town; 20 MJ was the monthly per capita energy consumption for these items in 1993-94 and it became 2.5 times (50 MJ) in 2011-12.

As contrary to energy consumption, monthly per capita CO_2 emission due to the consumption of these items has been fallen across all types of households during the study period. However, still the emission is concentrated towards the higher end (cluster D) of the consumption pattern cluster. These items are mainly for the high-income classes (as seen in the Figure 5.7). The energy consumption and related CO_2 emissions are quite high for the HIC households irrespective of the location.

h) Beverages & Processed Food

This consumption bundle is also an example of the difference in energy consumption due to consumption patterns. The per capita energy consumption due to beverages and processed food are comparatively very high for the households in cluster D, only, for both periods. That means, the HIC households in city and town together are the leader for energy consumption (see Figure 5.8). However, there is an improvement in energy consumption due to these items between these periods. Those households used to consume higher level of energy for consumption of beverages and processed food have dropped the per capita energy consumption considerably. This is truer for the energy-related CO_2 emission also. The monthly per capita CO_2 emission has dropped many times during the periods for those high pollutants. It is vividly observable that monthly per capita energy consumption and related CO_2 emissions are converging among the different types of households.

Figure 5.8: Beverages & Processed Food:
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

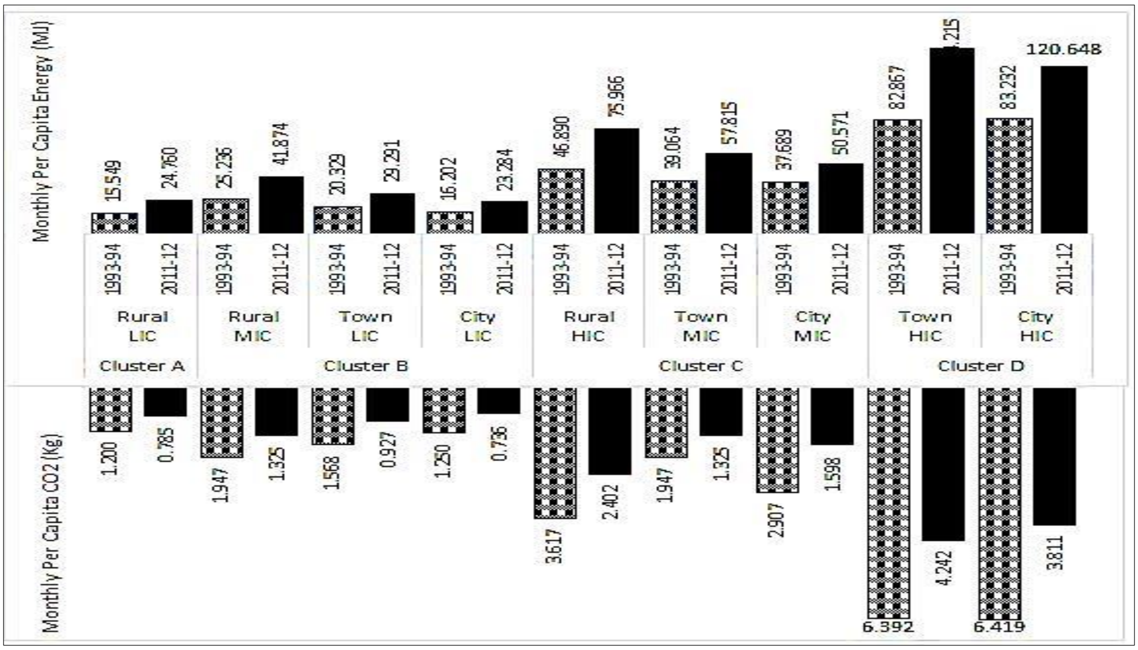
5.4.5. Non-Food Items

The non-food consumption items are also a very important aspect of energy studies. The non-food items have mainly embodied energy (indirect) within it while it was produced. The non-food items (excluding fuel and energy) have been classified into nine consumption bundles such as 1) clothing and footwear, 2) housing, 3) household durable goods, 4) education, 5) medical care, 6) amusement, 7) transportation, 8) other household goods, and 9) household services. The detailed analysis has been given below for all non-food consumption bundle.

i) Clothing & Footwear

The clothing and footwear is a matter of affordability. And the affordability of buying clothing and footwear is more to the HIC households than others households. As the expenditure on clothing and footwear is much more for households in cluster D, then related energy consumption is as well. The energy consumption is more for HIC households, specially the cluster D. Moreover, it has slightly increased over the 18 years of study periods. However, the energy consumption for cluster C is also relatively higher both the periods. More or less, the HIC households in cities and towns and HIC households in the rural area are consuming more energy due to clothing consumption bundle in 2011-12 and it is ever much higher than in 1993-94.

Figure 5.9: Clothing & Footwear:
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



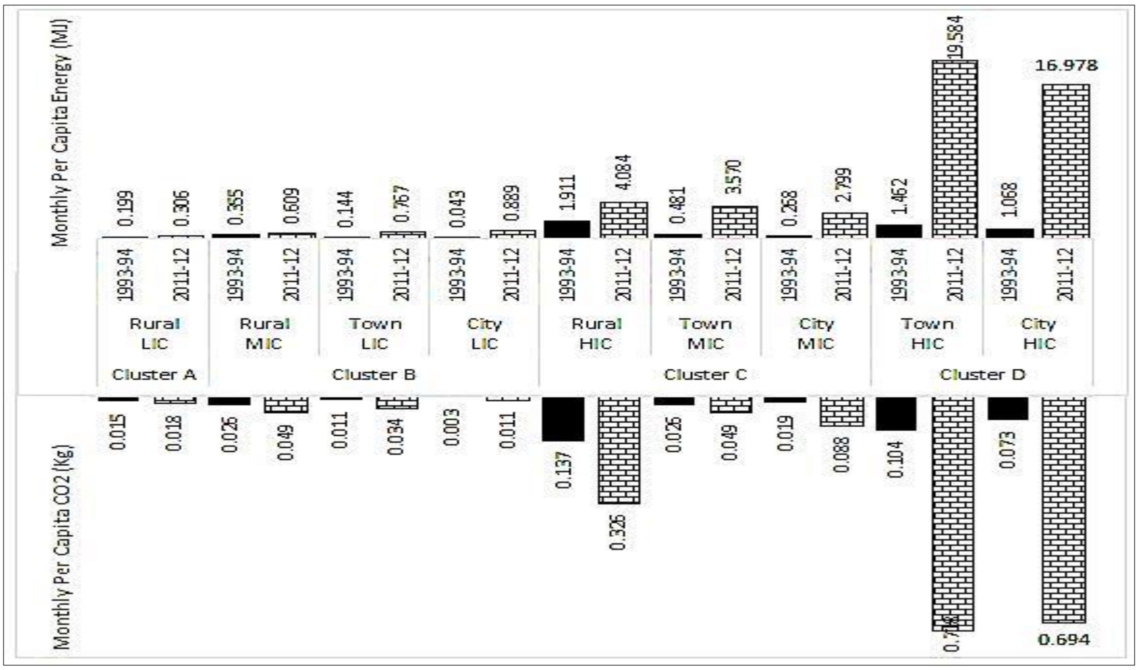
Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

Similar is the case for clothing and footwear-related CO_2 emission. The monthly per capita CO_2 emission is comparatively high for the HIC households. However, the good point is that the emission had declined over the period substantially for almost all sorts of households. However, still, there is a concentration of CO_2 emission for the households in cluster D.

j) Housing

The energy consumption and energy-related CO_2 emission for the housing extremely concentrated among the households in cluster D. The consumption bundle, 'housing' includes the all expenditure related to building the residential houses and its repairmen. It includes the rent paid for a rented house. This includes the bathroom equipment and electrical fittings also. HIC households everywhere were the major energy consumers and CO_2 emitters in 1993-94.

Figure 5.10: Housing:
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

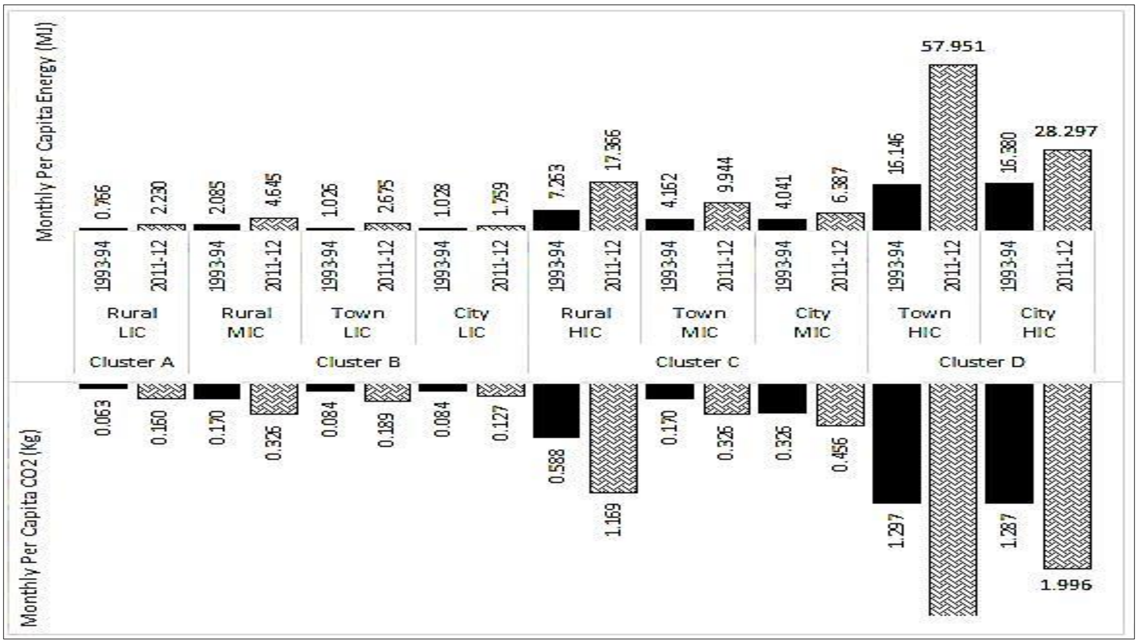
However, the scenario in 2011-12 is very different. The HIC households in towns and cities had consumed monthly per capita energy for housings extremely at high level. For example, in Town-HIC households, energy consumption due to housing, and construction activities were only 1.462 MJ monthly per capita in 1993-94, but it becomes about 19.5 MJ monthly per capita in 2011-12. Although the energy consumption has increased for all types of households, energy consumption for the HIC households in towns and cities is much higher than any other type of household.

There is a huge divergence in energy consumption and related CO_2 emission during the period. One contrary part in this consumption bundle is that the CO_2 emission has been increased for all sorts of households and these increases are extremely high in cluster D. in the absolute sense, the emission is low, but it was many-fold increases since 1993-94.

k) Household Durable Goods

All sorts of household's durable goods, household appliances, furniture and fixture, and crockery & utensils come under this consumption bundle. From Figure 5.11, it can be seen that the monthly per capita energy consumption is very high mainly in households of cluster D, HIC households in the city, and town. It was comparatively higher in 1993-94 and has been gone much further in 2011-12. One noticeable part is that the energy consumption (57 MJ in 2011-12) for HIC households in town is even much more than the same for HIC households in the city (28 MJ in 2011-12), unlike any other items. The higher income classes of all three settlement categories are consuming more energy than the other classes for consuming household durable goods. Similar is the case for energy-related CO_2 emissions. The monthly per capita CO_2 emissions had been increased for all types of households, but these are many more in HIC households in 2011-12.

Figure 5.11: Household Durable Goods:
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

I) *Other Household Goods*

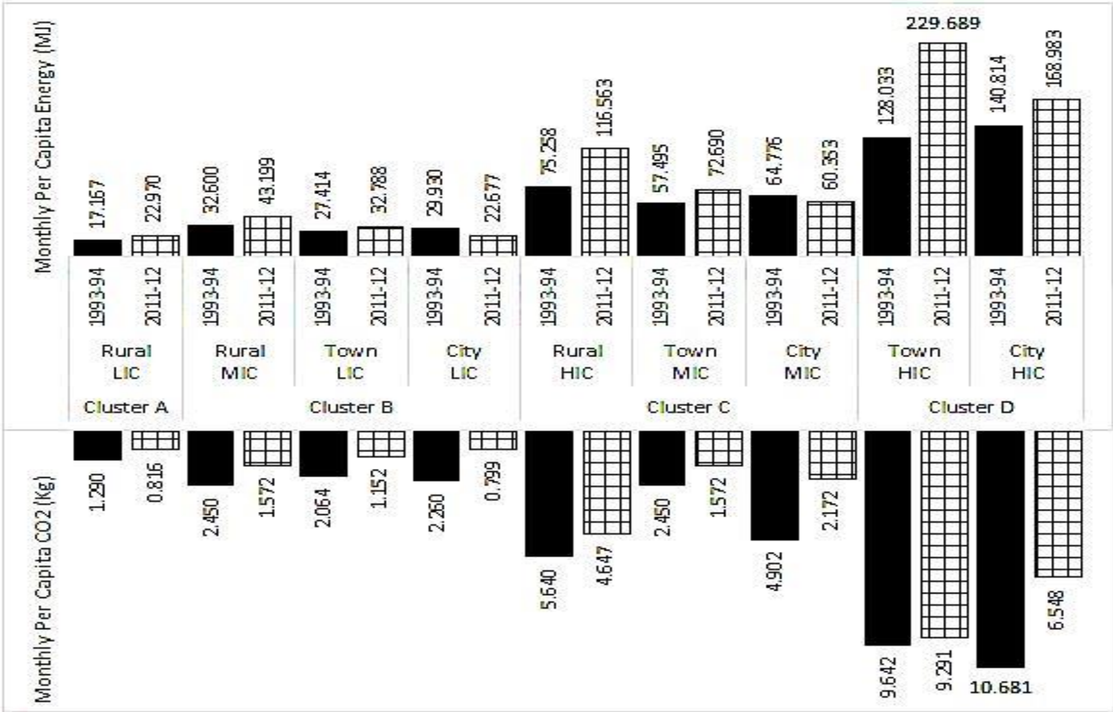
All types of minor durable goods, toilet articles, household's common goods, consumable personal goods and jewelary items are part of 'other household goods' consumption bundle[27]. The scenario is not different from other non-food consumption bundle. There is a large difference in energy consumption across different households. For example, the energy consumption for household goods was just 17.167 MJ in LIC households in rural and that was 140.814 MJ for HIC households in the city in 1993-94. That differential has gone farther in 2011-12. Although the energy consumption has increased for almost all types of households, it was more intense in HIC households. On the other hand, the energy-related CO_2 emission for the consumption of household goods

[27] A comprehensive list of consumption items and their consumption bundles has been given in Apendix-5A.

has been declined for all types of households. Still, the HIC households are the major contributors for energy-related CO_2 emission

Figure 5.12: Household Goods:

Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



Source: Author's calculation

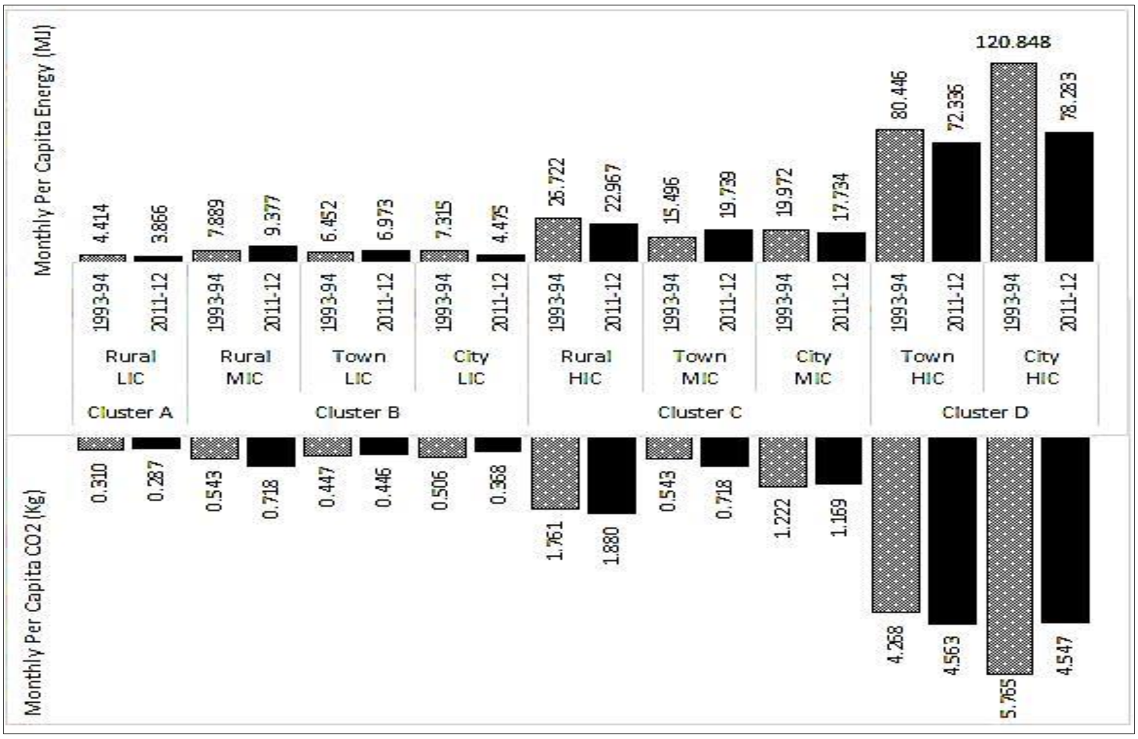
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

m) Household Services

Similar to the household goods, consumption of household services is also very high in households in cluster D. All sorts of services that a household receives come under this category. The energy consumed due to the consumption of household services is highly disproportionately distributed among the households. The HIC households in the city (120 MJ) and town (80 MJ) are using a high level of monthly per capita energy due to household services in 1993-94. The HIC households in the rural area are the distant third largest per capita energy consumers (26 MJ in 1993-94). However, it declined for all types of households from1993-94 to 2011-12. Almost similar is the case for CO_2 emission. HIC households are the main contributors. But, as in other households CO_2

emissions (monthly per capita) has declined, still that for HIC households in town and rural area has been gone up since 1993-94 to 2011-12.

Figure 5.13: Household Services:
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12

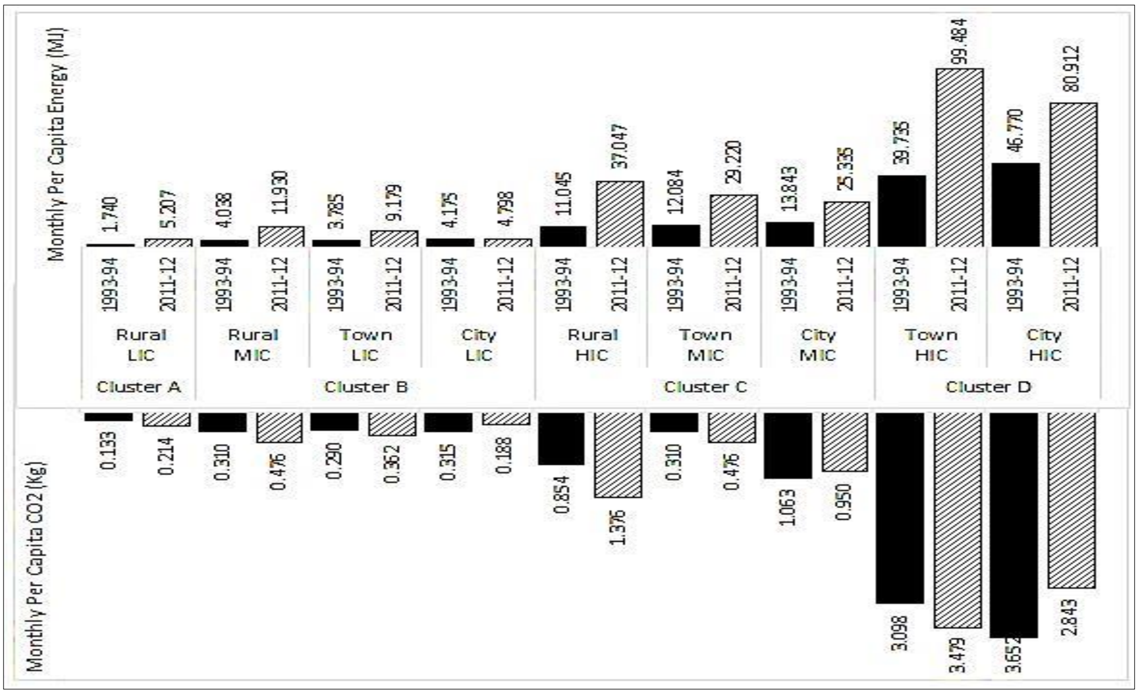


Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

n) Education

Education is an important part of human development. Spending on education is like investing in human capital for the future. All kinds of educational expenditures including school and college fees and private tuition fees come under it. Similar to the other non-food items, the energy consumption monthly per capita is also very higher for the HIC households in town and city. As it can be seen from Figure-5.14, there is a many-fold increase in consumption of energy consumption due to increase in expenditure for different education items, from 1993-94 to 2011-12. And the increase is more for the HIC households, in absolute terms. One important part is that as CO_2 emission has gone up for almost all types of households, only for the city households it gone slightly down during the study period.

<u>Figure 5.14: Education:</u>
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



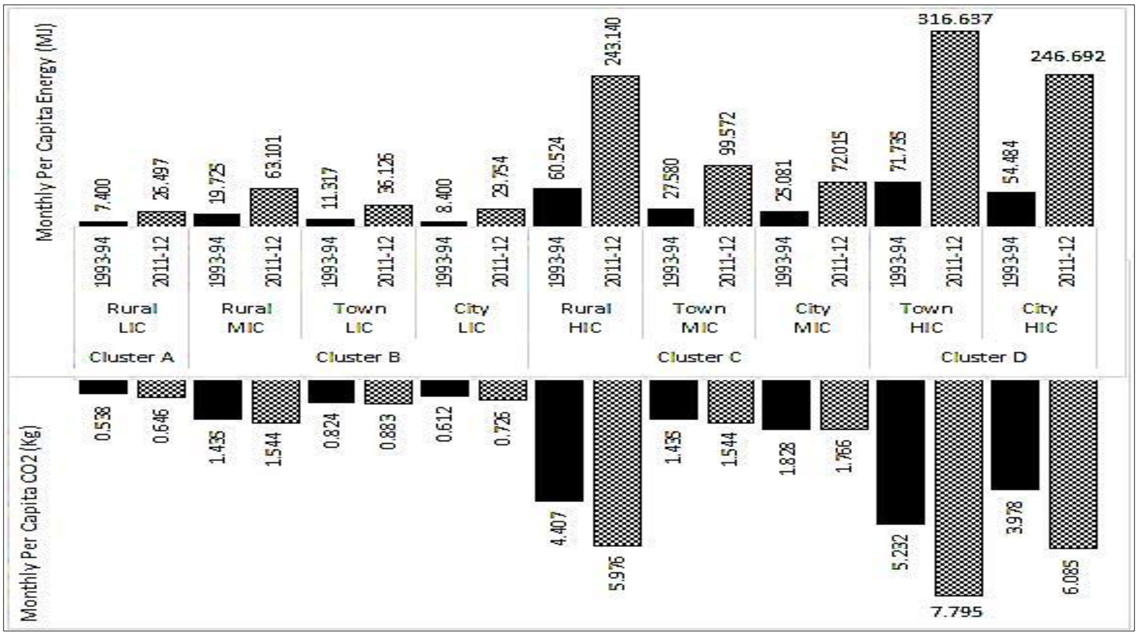
Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

o) Medical Care

Medical care is another item for HIC households only. As a high affordability issue attached with the medical care, so the spending for medical care is more for HIC households than other households. In Figure 5.15, it can be seen that the monthly per capita energy consumption was higher for HIC households in 1993-94 compared to other households and it has gone further higher in 2011-12. There is a huge divergence in energy consumption related to medical care.

Figure 5.15: Medical Care:

Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



Source: Author's calculation

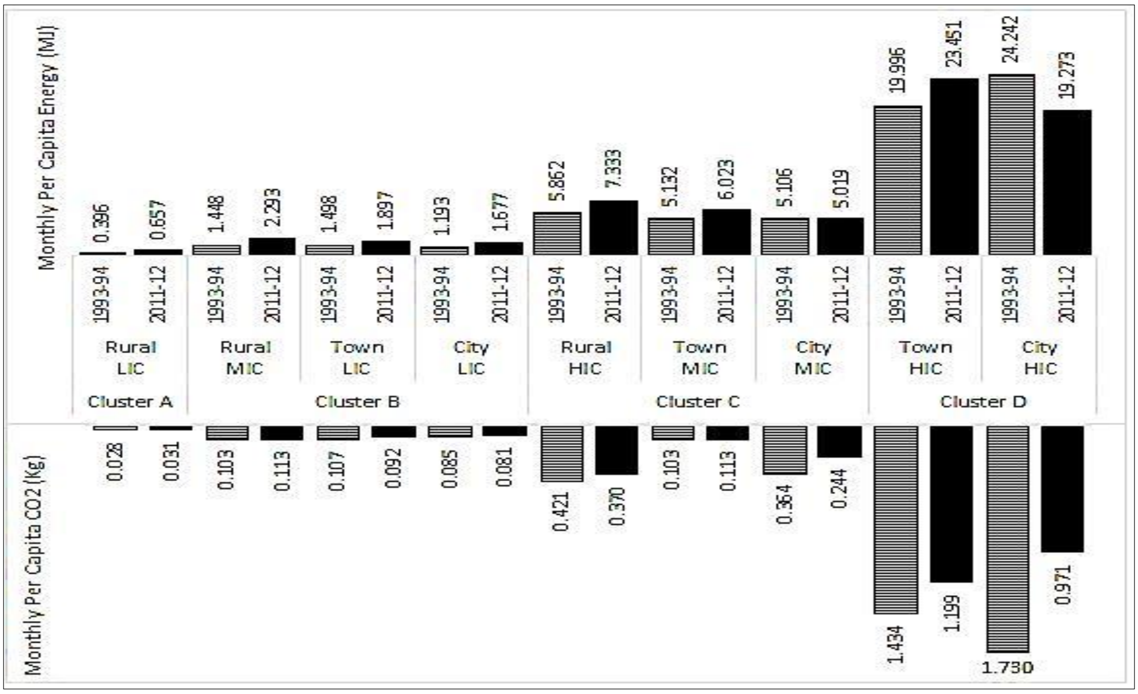
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

The medical care-related CO_2 emission is also very high for the HIC households and has increased in 2011-12 further. Although there was an increase in CO_2 emission for all households, it is significantly and higher for the HIC households since 1993-94.

p) Amusements

Amusements are the most urban phenomenon. Urban households tend to spend more on amusement and entertainment goods than rural households. The energy consumption and related CO_2 emission due to expenditure for recreation and amusement are very much cluster-specific. There is intra-cluster uniformity across the types of households within a cluster and it is true for all such clusters. On the other hand, there is an inter-cluster differential in energy consumption due to amusement purposes in India (Figure 5.16). As it can be seen in figure 5.16, the energy consumption due to amusement is mainly a matter for HIC households in the urban area. When the monthly per capita energy consumption was only 0.396 MJ for LIC rural households, then it was 24.242 MJ for HIC city households in 1993-94. And in 2011-12, when it is only 0.657 MJ for LIC rural households, then it is 23.451 MJ for HIC town households. Still, there is a huge difference in energy consumption. One important part is that when energy consumption has increased for all households, only the HIC city households whose energy consumption has been gone down during the same period.

Figure 5.16: Amusements:
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

The amusement-related CO_2 emission is also cluster-specific. There is a similarity in CO_2 emission within the cluster. However, the emission is much more for cluster D than the rest of the clusters. However, similar to energy consumption the CO_2 emission has declined in 2011-12 for cluster D. Still it remained at a high level than other clusters.

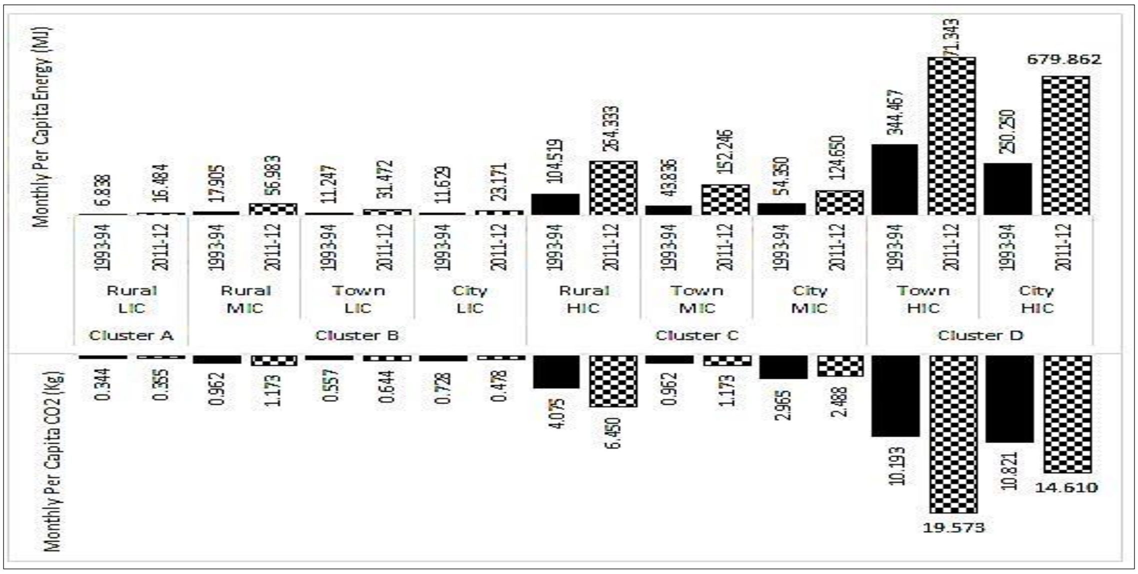
q) Transportation

The pattern of energy consumption and energy-related CO_2 emission for private transport activities is follows the same pattern as that of overall consumption expenditure taking items together. In cluster A, the rural lower-income class households used much less energy for transportation than that of higher-income class households in towns and cities (cluster D). However, the energy consumption has increased from 6.8 MJ monthly per capita in 1993-94 to about 16.8 MJ monthly per capita in 2011-12.

On the other hand, the monthly per capita energy consumption for transportation by the higher income class households was about 344 MJ in towns and was about 250 MJ in cities in 1993-94. These gone further increased in 2011-12. That increased amount even greater than the existing monthly per capita consumption for the rest of the types of households taken together (excluding HIC in towns) in 2011-12.

Besides, the energy consumption for cluster B is more than that of cluster A and cluster, C is more than that of cluster B for both periods. One point to be noted here that monthly per capita energy consumption for private transportation is highest for rural higher income class households within cluster C (i.e., higher than that of MICs in towns and cities. One of the main reasons is that the MIC in towns and cities can able to access the public transportation systems which are more intense in towns and cities.

Figure 5.17: Transportation:
Monthly Per Capita Energy and CO2 Emissions in 1993-94 and 2011-12



Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively.
MJ stands for Megajoules.

The pattern of CO_2 emission for energy consumption for private transportation is almost similar to that of energy consumption. As similar to energy consumption in most types of households, the energy-related CO_2 emission (monthly per capita basis) has increased from 1993-94 to 2011-12 (cluster A, cluster B, and cluster C excluding HIC in the rural area). It is more for HIC households and increased further. One important issue is that the emission is much more for HIC town households and its city counterpart.

Overall**,** analysis of data has revealed that on average, an Indian household used 801.585 MJ of energy monthly per capita in 1993-94. However, the energy consumption has increased more than double (about 217 per cent increases) in 2011-12, which is about 2542 MJ (monthly per capita). However, the increase for non-energy items during the same period is less than double (86 per cent increase, only). On the other hand, the increase in energy items is about 317 per cent during the same period. However, analysis of monthly per capita CO_2 emission showed mixed results during the same periods. The monthly per capita CO_2 emission has been increased by 18 per cent; from 60.276 kg in

1993-94 to 71.096 kg in 2011-12. In energy items, it is increased by 43 per cent over the period. And that is for the non-energy sector has gone down by 20 per cent over the same period.

The energy consumption from firewood and dung cake was at a very high level in 1993-94 in the rural area irrespective of the income classes, and even it became higher in 2011-12. The energy consumption from firewood and dung cake was at the highest level for higher-income class households in the rural area and still is at a higher level in 2011-12. As firewood and dung cake consumption is mostly a rural phenomenon, the consumption of coal and coke is mostly an urban phenomenon. In 1993-94, the urban areas, specifically towns, were the major user of coal and coke. The monthly per capita energy consumption and related CO_2 emission are both were high in all types of households in towns.

However, over 18 years, the rural areas are using more energy from coal than towns. The energy consumption from kerosene had gone change enormously during the same periods. It can be seen the highly skewed distribution of energy consumption from electricity in different types of households. The monthly per capita consumption level is extremely lower in households of clusters A and B. It is extremely high for the households in cluster D. whereas, it is moderately high for the households in cluster C. The energy-related CO_2 emissions from electricity consumption across the different types of households have a similar scenario as in the case of electricity energy consumption.

There was a huge difference in lower and higher ends of the consumption structures (0.404 Kg for LIC in rural and 23.926 Kg for HIC in the city) in 1993-94. There was an increase in CO_2 emission from electricity consumption across all types of households from 1993-94 to 2011-12. The consumption pattern for LPG is almost similar to the electricity consumption pattern. However, the monthly per capita LPG consumption is not uniform across households; in fact, it is still diverging. The increase of monthly per capita LPG was just about 2.48 MJ for cluster A, the lower income households in rural area; whereas the increase in monthly per capita LPG is more than 700 MJ in cluster D, the higher income households in city and town. The energy consumption from LPG is in increasing trend as moving from cluster A to cluster D for both the period. Similar to energy consumption, the energy-related CO_2 emission is skewed towards the cluster D (the higher end).

The findings of this chapter will be used in the next chapter (Chapter 6) to analyse the effects of consumption patterns of every consumption bundle across different income classes and across different settlement categories. The next chapter will apply the structural decomposition analysis to get the consumption patterns effects. And the measures of total energy consumptions and related CO_2 emissions have been used in structural decomposition analysis in next chapter.

Chapter - 6

Effects of Consumption Pattern on CO_2 Emission

6.1. Background

The energy related carbon emission patterns and factors influencing the carbon emission are important aspects considered for policy formulation. The energy studies provide policy options for the policy makers to come with appropriate policy instruments for addressing the problems of climate change. In addition to that, a decomposition analysis of total CO_2 emissions can find the other contributing factors for the emission. The de-carbonization policies or the rate of improvement of energy efficiency are the crucial parameters to be used to calculate the possible cost of climate policy scenarios (Albrecht, et al., 2002).

The two types of decomposition analysis have been widely used in energy research, namely “Structural Decomposition Analysis” (SDA) and “Index Decomposition Analysis” (IDA) (Ang and Zhang, 2000). The IDA is used in much literature in the fields of energy and environmental economics to analyse energy consumption and emission (Zhang et al., 2016; Carmona and Collado, 2016). On the other hand, SDA is more about analyzing the economic and technological effects based on the input-output framework (Achao and Schaeffer, 2009). In contrary to SDA, the IDA uses the concept of index numbers during decomposition analysis (Ang, 2004; Carmona and Collado, 2016).

In addition to that IDA has greater advantages of including the different forms of indicators, mathematical form, and indices (Zhang et al., 2016). The Laspeyres index decomposition and Divisia index decomposition analysis are the two main forms of IDA (Ang and Zhang, 2000; Carmona and Collado, 2016). Then the logarithmic mean Divisia index (LMDI), a form of Divisia index decomposition, is considered here as LMDI does not leave any residuals (Ang, 2005). However, Siegel (1945) and Shapley (1953) had shown that the two different approaches ultimately lead to the same results (Boer, 2009).

Lin and Chang (1996) had used the Divisia index approach for having decomposition changes in the emissions of SO_2, NO_x, and CO_2 from 1980 to 1992 in major economic sectors of Taiwan. They had studied the inter-relationship between usage of energy sources and the quality of the environment. The changes in emissions have been decomposed into five components such as pollution coefficient, fuel mix, economic growth, energy intensity, and structural change in industries. Chang and Lin (1998) had another study during the period 1981-1991 in Taiwan on emissions trends in industrial sectors. They applied the input-output based structural decomposition analysis and found the level of final demand and exports are the basic factors behind the rise of CO_2 emissions. They had also found that the major factor for emissions reduction was reducing CO_2 emission intensity in industrial sectors. The next important factor was the structure of the domestic final demand; however, the structural change in export had little effect on emission reduction.

This chapter focuses on the impact of change in consumption patterns on the energy-related CO_2 emission at households of different income classes and in different settlement categories. Many factors influence the increase or decrease of CO_2 emission. These include energy efficiency, CO_2 emission factor, overall economic activities, population and consumption patterns.

6.2. Sources of Data

The major and probably only source of information inter-sectorial transactions in India are the “Input-Output Transaction Tables” (IOTTs) prepared by “Central Statistical Organization” (CSO). The CSO publishes IOTTs for India almost every five-years interval. However, the latest IOTTs available for India is for the year 2007-08. Therefore, the IOTTs-2007-08 has been chosen as it is the latest for the year 1993-94 and 2007-08. Then the ‘Commodity X Commodity’ matrix is considered for the analysis. Since the IOTTs are calculated in current prices, then WPI from RBI has been considered to make IOTTs-2007-08 at a constant price, by considering 1993-94 as the base year. To make it hybrid IOTT, the energy statistics of CSO is used. By using IOTTs, Energy Statistics, and NCV (Net Calorific Value) from different Govt. documents, then energy intensity for aggregate production sectors had been calculated first for periods, 1993-94 and 2007-08. By using these information, the energy intensity and CO_2 emission intensity of every aggregated sectors of Indian economy have been measured in Chapter 3, for the years 1993-94 and 2007-08.

On the other hand, NSS unit-level data for Consumption expenditure survey 1993-94 and 2009-10 have been considered for the analysis of household consumption demand. All the households are classified according to their settlement categories, such as rural area town and city. The households also classified according to income classes. The million-plus cities urban area have been considered as the city, and the rest of the urban area is called the town. And the top 20 per cent of the population based on total per capita household consumption is considered for the higher-income class, and the bottom 20 per cent of the population is lower-income class. The rest of the population is the middle-income class. Each item of the household consumption listed in the NSS survey had been matched with the IOTTs production sections to get the energy embodied of each of those household consumption items. The estimates of household energy requirements, directly and indirectly, and estimates of related CO_2 emission from the analyses of previous chapters are used in the present chapter.

6.3. Analytical Framework

The well-known equation in environmental impact assessment is I = PAT, in which the environmental impact (I) is caused by the population (P), affluence (A), and Technology (T). The increasing world population has an adverse effect on the earth's environment. For the living of the increased population, economic activities are needed to be increased. As a result, the depletion of natural resources will increase and thence the related emissions. Therefore, lowering the population could help to lower the environmental impact (negative). The affluence is measured by the consumption (depletion) or emissions (pollution) per person.

The lowering per capita consumption of natural resources if that consumption is above the sufficiency level could able to lower the total consumption and hence lowering the total environmental impact (negative) (Achao and Schaeffer, 2009), more importantly, the factor T is technological efficiency. It enhances the level of affluence level without extra depletion of natural resources. The increasing use of renewable resources, the process of recycling, implementation of legal standards, the imposition of taxes, production-process efficiency is improving consumption efficiency. The energy-related CO_2 emission is the environmental (negative) impact caused due to consumption of different items by the households.

6.3.1. Decomposing CO_2 Emission at Aggregated level

The aggregated level of the per capita energy-related CO_2 emission can be decomposed through the Kaya Identity form as (Kaya, 1990):

$$\frac{CO2}{P} = \left(\frac{CO2}{E}\ x\ \frac{E}{TC}\ x\ \frac{TC}{P}\right) \text{ .... (6.1)}$$

Where, CO_2 is the total emission of CO_2 (energy-related), E is the total energy used, TC is the total consumption expenditure and P is the total population. The environmental impact (CO_2 emission) can be caused by population P, level of affluence (TC/P – per capita household consumption), and the two technological factors such as energy efficiency (E/TC) and (CO_2/E).

The ratio between CO_2 and E gives the measures of CO_2 emission per unit of energy consumption and it is called CO_2 emission intensity (CI). The ratio, E/TC is called the energy intensity (EI) which is nothing but the energy used per unit household consumption expenditure. The TC/P is the per capita household consumption which is the reflector of the level of activity (A). The Kaya Identity can be written as (Kaya, 1990):

$$CO2/P = \left(\frac{CO2}{E}\ x\ \frac{E}{TC}\ x\ \frac{TC}{P}\right) = [(CI)\ x\ (EI)\ x\ (A)] \text{ .... (6.2)}$$

The Per Capita CO_2 emission is the product of CO_2 emission intensity (CI), Energy Intensity (EI), and Activity Share (A).

The change in per capita CO_2 emission from base year, t_0 to terminal year, 'T', can be written as (Zhang and Ang, 2001):

$$\Delta CO2_{pc} = CO2^{T} - CO2^{t_0} = [CI^{T} EI^{T} A^{T}] - [CI^{t_0} EI^{t_0} A^{t_0}] \text{ ……….. (6.3)}$$

According to the logarithmic mean Divisia index (LMDI) approach, the $\Delta CO2_{tot}$ can be decomposed as follows (Ang et al., 1998; Zhang and Ang, 2001):

$$\Delta CO2_{pc} = \{\Delta CO2_{C-int} + \Delta CO2_{E-int} + \Delta CO2_{act}\} \text{ ……………….. (6.4)}$$

Where, $\Delta CO2_{C-int}$, $\Delta CO2_{E-int}$, and $\Delta CO2_{act}$ denote the CO_2 emission intensity effects (CIE), energy intensity effects (EIE), and activity effects (AE), respectively. $\Delta CO2_{C-int}$ is the change of total CO_2 emission between the two periods due to a change in CO_2 emission intensity. $\Delta CO2_{E-int}$ is the change in CO_2 emission due to a change in energy intensity. Similarly, $\Delta CO2_{act}$ *is* the same, due to a change in per capita consumption (activity). The separate estimates of each component measure the contributions of each such factor in the change in per capita CO_2 emissions between two periods. The LMDI approach is applied here to measure the decomposition components of these per capita CO_2 changes (Ang, 2005).

Let, $CO2^{t_0}$ and $CO2^{T}$ are the per capita energy-related CO_2 emission in periods, respectively. According to LMDI approach, the changes of CO_2 emission is due to change in CO_2 emission intensity can be obtained as (Ang et al., 1998; Ang, 2005):

$$\Delta CO2_{C-int} = L\,(CO2^{T}, CO2^{t_0}) \ln \left[\frac{CI^{T}}{CI^{t_0}}\right] \text{ ……………….. (6.5)}$$

Now, let, $L\ (CO2^{T}, CO2^{t_0}) = \frac{(CO2^{T} - CO2^{t_0})}{\ln CO2^{T} - \ln CO2^{t_0}}$, which is logarithmic change of CO_2 emission of two periods. And $\ln\left[\frac{CI^{T}}{CI^{t_0}}\right]$ is the logarithmic form of change of CO_2 emission intensity of two periods.

Hence, the change in CO_2 emission due to change in CO_2 emission intensity can be as (Zhang and Ang, 2001):

$$\Delta CO2_{C-int} = \frac{(CO2^{T} - CO2^{t_0})}{\ln CO2^{T} - \ln CO2^{t_0}} \ln\left[\frac{CI^{T}}{CI^{t_0}}\right] \quad\text{......................................(6.6)}$$

Similarly, the changes of per capita CO_2 emissions, during the periods (t_0,T), due to changes in energy intensity, change in activity can also be obtained as (Ang et al., 1998):

$$\Delta CO2_{E-int} = L(CO2^{T}, CO2^{t_0}) \ln\left[\frac{EI^{T}}{EI^{t_0}}\right] = \frac{(CO2^{T} - CO2^{t_0})}{\ln CO2^{T} - \ln CO2^{t_0}} \ln\left[\frac{EI^{T}}{EI^{t_0}}\right] \quad\text{......(6.7)}$$

$$\Delta CO2_{act} = L(CO2^{T}, CO2^{t_0}) \ln\left[\frac{A^{T}}{A^{t_0}}\right] = \frac{(CO2^{T} - CO2^{t_0})}{\ln CO2^{T} - \ln CO2^{t_0}} \ln\left[\frac{A^{T}}{A^{t_0}}\right] \quad\text{...............(6.8)}$$

The advantage of the LMDI approach is that it does not leave any residual term (Ang, 2005), and hence the sum of all of these decomposed components resulted in the change in per capita CO_2 emission, perfectly (Ang et al., 1998). Hence,

$$\Delta CO2_{pc} = \frac{(CO2^{T} - CO2^{t_0})}{\ln CO2^{T} - \ln CO2^{t_0}} \left\{\ln\left[\frac{CI^{T}}{CI^{t_0}}\right] + \ln\left[\frac{EI^{T}}{EI^{t_0}}\right] + \ln\left[\frac{A^{T}}{A^{t_0}}\right]\right\} \quad\text{............ (6.9)}$$

The right-hand side of Equation (6.9) is the change of per capita CO_2 emissions. If the right-hand side is got expanded, then it became the sum of three components. The first component gives the measure of the change of per capita CO_2 emission due to change of CO_2 emission intensity. Similarly, the second and third components give the same due to change in energy intensity and change in activity, respectively.

6.3.2. Decomposing CO_2 Emission at Disaggregated level

The decomposition analysis has been further extended among the different consumption item-groups to capture the effects of consumptions items on per capita CO_2 emission. Suppose that there is a total 'n' number. of consumption bundles. Hence, the per capita CO_2 emission by any type of households can be obtained as:

$$\frac{CO2}{P} = \sum_{i=1}^{n} \frac{CO2_i}{E_i}\ x\ \frac{E_i}{CE_i}\ x\ \frac{CE_i}{TC}\ x\ \frac{TC}{P} = \sum_{i=1}^{n} (CI_i)(EI_i)(CP_i)(A) \text{ …….. (6.10)}$$

Where, $\frac{CO2_i}{E_i}$ is the CO_2 emission intensity (CI_i) for the i^{th} consumption item group. It measures the CO_2 emission intensity per unit of energy use (direct and indirect) for the i^{th} consumption group. Similarly, $\frac{E_i}{CE_i}$ is the total energy usage (direct and indirect) per unit of consumption expenditure on i^{th} consumption item group which is known as the energy intensity (EI_i) for i^{th} consumption group. The ratio of consumption expenditure on i^{th} consumption groups to the total consumption of a particular household type, $\frac{CE_i}{TC}$ measures the consumption pattern effects. And the per capita total consumption expenditure is (TC/P).

Hence, the change in per capita CO_2 can be obtained by taking the difference for the two periods, say 0 and T.

$$\Delta CO2 = \left\{\sum_{i=1}^{n} CO2_i^T - \sum_{i=1}^{n} CO2_i^{t_0}\right\}$$

$$= \left\{\sum_{i=1}^{n}[(CI_i^T)(EI_i^T)(CP_i^T)(A^T)] - \sum_{i=1}^{n}\left[\left(CI_i^{t_0}\right)\left(EI_i^{t_0}\right)\left(CP_i^{t_0}\right)\left(A^{t_0}\right)\right]\right\} \text{ ……... (6.11)}$$

According to the LMDI, the total change in per capita CO_2 emission can be obtained by summing up (Ang et al., 1998; Ang, 2005).

$$\Delta CO2_{pc} = \{\Delta CO2_{C-int} + \Delta CO2_{E-int} + \Delta\, CO2_{patt} + \Delta CO2_{act}\} \ldots\ldots\ldots\ldots\ (6.12)$$

$$L\left(CO2_i^T, CO2_i^{t_0}\right) = \sum_{i=1}^{n} \frac{\left(CO2_i^T - CO2_i^{t_0}\right)}{\ln CO2_i^T - \ln CO2_i^{t_0}}$$

$$L\left(CO2^T, CO2^{t_0}\right) = \frac{\left(CO2^T - CO2^{t_0}\right)}{\ln CO2^T - \ln CO2^{t_0}}$$

Table-6.1: The Measures of Different Effects of Four Components in SDA			
A.	CO_2 Emission Intensity Effect (CIE)	$\Delta CO2_{C-int}$	$= \sum_{i=1}^{n} \frac{\left(CO2_i^T - CO2_i^{t_0}\right)}{\ln CO2_i^T - \ln CO2_i^{t_0}} \ln\left[\frac{CI_i^T}{CI_i^{t_0}}\right]$
B.	Energy Intensity Effect (EIE)	$\Delta CO2_{E-int}$	$= \sum_{i=1}^{n} \frac{\left(CO2_i^T - CO2_i^{t_0}\right)}{\ln CO2_i^T - \ln CO2_i^{t_0}} \ln\left[\frac{EI_i^T}{EI_i^{t_0}}\right]$
C.	Consumption Pattern Effect (CPE)	$\Delta CO2_{patt}$	$= \sum_{i=1}^{n} \frac{\left(CO2_i^T - CO2_i^{t_0}\right)}{\ln CO2_i^T - \ln CO2_i^{t_0}} \ln\left[\frac{CP_i^T}{CP_i^{t_0}}\right]$
D.	Activity Effect (AE)	$\Delta CO2_{act}$	$= \frac{\left(CO2^T - CO2^{t_0}\right)}{\ln CO2^T - \ln CO2^{t_0}} \ln\left[\frac{A^T}{A^{t_0}}\right]$

Therefore, the total change in CO_2 emission during the two periods can be summed up as:

$$\Delta CO2_{tot} = \{\Delta CO2_{C-int} + \Delta CO2_{E-int} + \Delta\, CO2_{patt} + \Delta CO2_{act}\} \ldots\ldots\ldots\ldots (6.13)$$

The expanded form of the above equation is as (Ang et al., 1998):

$$\Delta CO2_{tot} = \sum_{i=1}^{n} \left\{ \frac{\left(CO2_i^T - CO2_i^{t_0}\right)}{\ln CO2_i^T - \ln CO2_i^{t_0}} \left(\ln\left[\frac{CI_i^T}{CI_i^{t_0}}\right] + \ln\left[\frac{EI_i^T}{EI_i^{t_0}}\right] + \ln\left[\frac{CP_i^T}{CP_i^{t_0}}\right] \right) \right\} +$$

$$\left\{ \frac{\left(CO2^T - CO2^{t_0}\right)}{\ln CO2^T - \ln CO2^{t_0}} \left(\ln\left[\frac{A^T}{A^{t_0}}\right] + \ln\left[\frac{P^T}{P^{t_0}}\right] \right) \right\} \ldots\ldots\ldots\ldots\ (6.14)$$

The right-hand side provides the change of CO_2 emission over the two periods. After expanding the right-hand side of the Equation 6.14, the first component gives the measure of change of CO_2 emission solely due to change in CO_2 intensity effects. The second, fourth and fifth components are the measures of the change of CO_2 emissions are due to energy intensity, change in activity, and change in population, respectively. The third component is most important for analysis in this chapter. This component gives the measures of change in CO_2 emission due to change in household consumption patterns.

6.4. Decomposition Effects of CO_2 Emission in India

6.4.1. CO_2 Decomposition Effects at Aggregate level

At all India level, the monthly per capita CO_2 emission in 2011-12 was about 71 kg which was about 11 kg more (18 per cent increase) than that of 1993-94. This increase in CO_2 is due to activity effects. However, there is a decrease in CO_2 emission due to CO_2 intensity effects and energy intensity effects. Commodities became less polluting now, but since the consumption had increased (activity effect) much more, the net CO_2 emission had increased. This situation can be interpreted through the rebound effect.

The monthly per capita CO_2 emissions (MPCCE) is highest for HIC households (106 kg of CO_2) among other income classes households in 2011-12 and for rural households (73 kg of CO_2) among other households in different settlement categories. However, households in cities and towns are not far from rural households. The change of CO_2 emission is relatively high for rural households; it is increased by 13.64 kg of CO_2 monthly per capita from 1993-94 to 2011-12. The increase for town and city are very insignificant. On the other hand, HIC and MIC households increased their emission by 11 kg of MPCCE by that time.

Table 6.2: ***CO_2 Decomposition Effects* at the aggregate level between 1993-94 and 2011-12**

Income Classes	MPCCE in 2011-12 (Kg CO2)	Change in MPCCE (Kg CO2)	Change of CO2 (%)	CO2 Intensity Effects (Kg CO2)	Energy Intensity Effects (Kg CO2)	Activity Effects (Kg CO2)
Rural All	73.03	13.64	22.96	-16.26	-1.04	30.93
Town All	64.27	3.75	6.19	-21.73	-17.06	42.48
City All	72.37	0.38	0.53	-26.75	-23.43	50.55
All HIC	106.55	11.02	11.53	-40.52	-19.42	70.96
All MIC	65.60	9.75	17.45	-15.24	-4.87	29.84
All LIC	49.47	11.23	29.37	-5.17	-2.70	19.04
All India	71.10	10.82	17.95	-19.20	-8.46	38.46

Source: Author's calculation

Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively; MPCCE stands for Monthly Per Capita CO_2 Emission.

For the decomposition effects, CO_2 emission had declined for all types of households due to CO_2 intensity effects; commodities became less carbon intense than before. This decrease is very high for HIC households (about 40 kg) and lows for LIC households (about 5 kg). MPCCE had been declined for all households due to energy intensity effects also. Overall, commodities in India became less energy-intense. There was a significant decline of CO_2 emission in average households in towns and cities, and also in HIC households than other income classes. On the other hand, an overall increase in MPCCE is due to increase consumption, activity effects for all households in India. Which are very high for HIC households and households in the city.

6.4.2. CO_2 Decomposition Effects in Different Households in Different Settlement Categories

In the previous section, the MPCCE had been increased by the highest amount for HIC households. However, it is not possible to say whether these HIC households settled in city or town, or rural area. Therefore, a further classification of households is required for this decomposition analysis. Table 6.3 provides the results with such classification of households.

Table 6.3: SDA of Different Households in Different Settlement Categories							
		MPCCE in 2011-12 (Kg CO2)	Per CapitaCO2 Change (Kg CO2)	Change of CO2 (%)	CO2 Intensity Effects (Kg CO2)	Energy Intensity Effects (Kg CO2)	Activity Effects (Kg CO2)
Cluster A	Rural-LIC	51.25	13.25	34.86	-4.48	0.19	17.54
Cluster B	Rural-MIC	70.50	14.96	26.94	-12.73	1.27	26.42
	Town-LIC	45.16	5.45	13.71	-6.50	-9.62	21.39
	City-LIC	29.28	-2.49	-7.83	-3.51	-8.52	9.43
Cluster C	Rural-HIC	102.35	10.08	10.92	-37.37	-6.61	54.06
	Town-MIC	55.54	-2.14	-3.71	-21.67	-14.81	34.29
	City-MIC	43.39	-9.81	-18.44	-16.67	-12.82	19.67
Cluster D	Town-HIC	123.38	22.17	21.91	-37.33	-33.43	92.93
	City-HIC	106.68	-5.45	-4.86	-38.66	-38.00	71.20

Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively; MPCCE stands for Monthly Per Capita CO_2 Emission.

Table 6.3 shows that the MPCCE is far more in HIC households irrespective of settlement categories. Even an average rural HIC household is emitting 102 kg of MPCCE in 2011 which is almost the same as HIC household in the city (about 106 kg MPCCE). However, the highest emitter is the HIC households in town in 2011-12. And the LIC households in the city are the least emitters – only 29.28 kg of MPCCE in 2011-12. For per capita change, HIC households in town come first, again with by 22 kg MPCCE during the period.

MPCCE had been increased by a significant level in all rural households, irrespective of income classes. One important result is that there is a net decline of MPCCE for households in the city, even for HIC households. The combined effects of declined CO_2 emission intensity and energy intensity played a more important role than the increase in activity effects. The net increase in CO_2 emission in rural areas had been increasing mainly the activity effects. The increases in consumption played more than the combined effects of CO_2 and energy intensity. HIC households in rural and town are the vivid example of increasing consumption effects. Their consumption level increased such a high level that it can easily overcome the combined declined of CO_2 due to both the intensity effects.

6.4.3. Consumption Pattern Effects (CPE) of Energy Items

All the sources of energy directly consumed in Indian households have been grouped into major six groups. These are a) Coal, Coke, Gas, b) Firewood and Dung Cake, c) Kerosene, d) Electricity, e) LPG, and f) Other Petroleum Products. Among these six groups, the first three groups are considered to be the traditional sources of energy and the last three groups are the modern sources of energy. The energy items are the important players in MPCCE for all types of households. Out of the total monthly per capita, CO_2 emissions almost 80 per cent to 50 per cent are due to the consumption of energy items.

The higher the absolute value of consumption pattern effects (CPE), the higher is the intensity to influence CO_2 emission by changing the consumption. In table-6.2, below, the absolute value of Rural LIC (14.34) and Rural MIC (12.18) classes provides evidence of a strong association between consumption patterns and CO_2 emission. And the positive association reveals that a large part of the increase in CO_2 emission is due to an increase in the consumption of energy items by these households. The lower values of CPE provide a weaker association between consumption and emission.

Table 6.4: Consumption Pattern Effects (Kg Per Capita) in CO2 Emission for Energy Consumption Bundles									
	Cluster A	Cluster B			Cluster C			Cluster D	
	Rural LIC	Rural MIC	Town LIC	City LIC	Rural HIC	Town MIC	City MIC	Town HIC	City HIC
Coal, Coke & Gas	2.26	0.33	-0.14	0.07	-3.64	-4.34	-0.90	-4.04	-0.61
Firewood and Dung Cake	9.68	6.74	-0.72	3.08	-14.75	-8.74	-0.54	-7.36	-0.56
Kerosene	0.98	0.93	0.04	-2.08	-0.18	-1.58	-2.57	-2.36	-1.94
Electricity	1.28	2.98	2.62	1.81	5.40	4.31	3.79	7.37	3.21
LPG	0.05	0.69	1.72	1.58	2.89	3.18	2.99	-0.14	-1.34
Other Petroleum Products	0.09	0.51	0.24	0.04	2.44	1.25	0.68	3.95	1.29
Total Energy	**14.34**	**12.19**	**3.76**	**4.50**	**-7.85**	**-5.93**	**3.45**	**-2.57**	**0.05**

Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively;

The negative values of CPE, for example, Rural HIC, Town MIC, and Town HIC provide the fact about the negative association between consumption of energy items and CO_2 emissions. The CPE of different energy items gave a different result for different households. Households in cluster A, have a positively strong association between Coal, firewood, and dung cake consumption and related CO_2 emission. For these traditional sources of energy, the CPE values are negatively strong for households in clusters C and D.

On the other hand, in these two clusters, electricity and LPG have strong positive values – reflecting a strong association between electricity and LPG consumption and related CO_2 emission. For the above results, it can be said that LIC and MIC households in rural areas have a larger role in CO_2 emission due to the consumption of traditional energy sources like coal, firewood, and dung cake. Whereas, for modern energy sources like electricity, LPG, and other petroleum products, the households in clusters C and D have a larger role in CO_2 emission due to consumption.

6.4.4. Consumption Pattern Effects (CPE) of Food Consumption Bundle

The consumption pattern effects (CPE) from the structural analysis for the food items have been tabulated in Table 6.3. The first thing to be noted here that along with fruits and other food items, the CPEs are negative for cereals, pulses, and vegetables for all households. The marginal effects of consumption share of those items are negatives – it implies the fall of emission due to the reduction of those shares. And the decline of Monthly Per Capita CO_2 Emission (MPCCE) for these above-mentioned items is more in HIC households especially in cluster D as their consumption level is also higher relative to other households.

Table 6.5: Consumption Pattern Effects (Kg) in CO2 Emission for Food Consumption Bundles

	Cluster A	Cluster B			Cluster C			Cluster D	
	Rural LIC	Rural MIC	Town LIC	City LIC	Rural HIC	Town MIC	City MIC	Town HIC	City HIC
Food: Cereals, Pulses, Vegetables	-1.10	-1.86	-1.73	-1.16	-2.95	-2.79	-1.91	-4.65	-4.42
Food: Milks, Egg, Fish, Meats	0.07	0.08	0.04	0.05	-0.14	-0.14	-0.14	-0.76	-0.84
Food: Others	0.05	-0.08	-0.27	-0.37	-0.84	-0.90	-0.78	-2.22	-2.25
Fruits	0.01	0.04	0.001	-0.05	0.02	-0.02	-0.07	-0.31	-0.66
Beverages & Processed Foods	-0.16	-0.42	-0.54	-0.56	-1.37	-1.48	-1.82	-5.65	-7.07
Total Food	**-1.12**	**-2.25**	**-2.49**	**-2.10**	**-5.29**	**-5.32**	**-4.72**	**-13.59**	**-15.24**
Pan, Tobacco & Intoxicants	-0.06	-0.09	-0.12	-0.08	-0.27	-0.27	-0.21	-0.91	-0.90

Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively;

There has been a strong association (but, negative) between CO_2 emission and food consumption in households in clusters C and D during the study period. The monthly per capita CO_2 emission has been declined for those households, due to decline in consumption of these items. More specifically, it has shown that CO_2 emission declined for cereals, pulses, and vegetables due to a decline in consumption in Cluster C and D. And that of Beverages & processed food for cluster D. However, the effects of CPE is relatively less for other types of households as there was less scope to replace the essential food items.

6.4.5. Consumption Pattern Effects (CPE) of Non-food Consumption Bundles

The non-food consumption bundles include all the consumption items except foods, pan, tobacco, intoxicant, and all the energy items. All kinds of domestic services or services taken by the households are incorporated here. The non-food consumption bundles became the most important consumption bundles, after energy items, because of it differential consumption pattern in different households. The levels of MPCCE for the non-food items are extremely high for the HIC households in cities and towns compare to the rest of the households. Almost 40 per cent of the CO_2 emissions by these households are coming from the high consumption of non-food items.

Table 6.6: Consumption Pattern Effects (Kg) in CO2 Emission for Non-Food Consumption Bundles

	Cluster A	Cluster B			Cluster C			Cluster D	
	Rural LIC	Rural MIC	Town LIC	City LIC	Rural HIC	Town MIC	City MIC	Town HIC	City HIC
Clothing & Footwear	0.05	0.11	-0.19	0.04	-0.27	-0.54	-0.29	-1.91	-1.49
Housing	0.01	0.01	0.001	0.01	0.06	0.02	0.02	0.07	0.12
Household Effects	0.04	0.06	0.05	0.08	0.10	0.07	0.18	0.41	0.46
Education	0.10	0.27	0.15	0.19	1.13	0.57	0.62	2.26	2.95
Medical Care	0.03	0.03	0.08	0.09	0.89	0.30	0.31	1.26	2.29
Amusement	0.02	0.08	0.07	0.07	0.23	0.29	0.32	0.34	0.43
Transportation	0.17	0.58	0.32	0.41	3.15	1.70	1.68	9.25	10.15
Household Goods	0.16	0.23	0.02	-0.14	0.45	0.02	-0.30	0.83	-1.14
Household Services	0.13	0.47	0.28	0.23	0.91	0.94	1.01	1.96	2.48
Total Non-Food	**0.55**	**1.54**	**0.78**	**0.88**	**6.23**	**3.38**	**3.47**	**14.68**	**16.22**

Source: Author's calculation
Note: LIC, MIC and HIC stand for Lower, Middle and Higher income classes, respectively;

The CPE values are very high for overall non-food items for Cluster D and moderately high for cluster C. The result shows that increase in consumption of non-food items had given a large contribution to the increase in CO_2 emission for households in clusters C and D. On the other side, the households of clusters A and B have a lesser role in CO_2 emission due to an increase in the consumption of non-food items.

Overall, analysis has shown that almost all types of households have a large role in contributing CO_2 emission due to the consumption of energy items. Specifically, for transitional sources of energy, the households in clusters A and B have a larger contribution. And for modern sources of energy, the households in clusters C and D have a larger contribution to CO_2 emission. For food items, the households in clusters C and D had played a crucial role in reducing CO_2 emission due to consumption, mainly of cereals, pulses, and vegetables. The households in cluster C and D have contributed larger CO_2 emissions due to an increase in the consumption of non-food items, mainly transportation, education, and medical care. The households in Cluster A and B, have a lesser role in contributing CO_2 emission due to the consumption of food and non-food items.

Chapter – 7

Summary of Findings & Conclusion

7.1. Background

The climate change is one of the most vital environmental challenges. Not only it can affect the production of food and fresh water supply, but can damage our health systems unbearable to the changing climates. Overall, it can damage our whole natural ecosystems. The climate change is considered as the side-effect of the rapid economic process. Various human induced activities, especially the combustion of fossil fuels, are considered as main causes for increasing CO_2 concentration and other GHGs. A country's sustainable development goals are getting affected by the ability of that country to cope up with the climate change and its impact on the economy. In this aspect, a developing country has a drawback to fight against the climate change. The developing countries are less equipped and have little resources to make policies for the climate change.

The Indian subcontinent is the most vulnerable area affected highly by climate change. It is due to its high dependency on agriculture and forestry which are highly climate-sensitive. The change of climate affects the temperature, rainfalls, and causes immense flood and dryness unpredictably and frequently. India is facing frequent incidences of heavy rainfall and flood on one side, and dryness on the other side – experiencing the extreme climatic conditions. According to the estimates of IEA (2011), India is the sixth-largest CO_2 emitter in the world; though India's position was much below based on per capita emission. However, India has tripled its annual emission from less than 600 metric tons to 1600 metric tons between 1990 and 2009 (IEA, 2011). Therefore, it is a need of the time to search for the scope of reducing the environmental load from the Indian economy.

Households affect the environment through their everyday decisions on consumption. Any effort to reduce the environmental pressure, such as energy efficiency technologies, has failed to draw desirable gains as it has overweighed by the increase in the consumption of goods and services through an increase in the world population, and hence the economic activity. The environmental impact from the consumption of goods and services by households is continuously increasing over the years.

Some reasons can be drawn behind the justification of the study of household consumption patterns and energy requirements. Households are one of the major consumers of energy and contribute, to a large extent, to the total energy use of any economy. Indian households together are using more than 40 per cent of the total direct commercial and noncommercial indigenous energy use. There are so many socio-economic, cultural, demographic, geographic, environmental factors that can affect the household behaviour on the choice of a particular commodity among the others. In such a way, the demand for household energy is also influenced by these factors. So, the success of any supply-side scheme also depends on the factors of the demand side mechanism.

This study had focused on the following objectives:

1. To analyse the consumption patterns of the households of different income classes across different size settlement categories over the period 1993-94 to 2011-12 in India.
2. To estimate the direct energy requirement and related CO_2 emissions at household level by different income classes across settlement categories over the same study period.
3. To compute the total energy requirement, direct and indirect at household level by different income classes across different settlement categories.
4. To analyse the energy-related total CO_2 emission, directly and indirectly, at household level by different income classes across different settlement categories.
5. To analyse the effects of household consumption patterns on the energy-related CO_2 emissions at household level by different income classes across different settlement categories over the period, 1993-94 to 2011-12.

The present study used two major data sources; NSS consumption expenditure and CSO input-output transaction tables. All the households were classified into nine aggregated classes depending upon the per capita income of the households and their settlement category. The study had investigated the unit level of the NSS consumption expenditure data. It tried to provide a basic understanding of household consumption patterns and their direct energy use and related CO_2 emission.

The model of multi-dimensional scaling (MDS) had been applied. This study also used other methods like energy input-output analysis and structural decomposition analysis (SDA). Through the energy input-output analysis, this study had calculated the energy intensity and related CO_2 emission intensity of aggregated sectors of the economy. That intensity was essential to calculate the total energy consumption and related CO_2 emission by the households through their final consumption. The SDA was used here to find the differential and partial influence of changing consumption patterns on the energy consumption and CO_2 emission, separated from the other factors. The method of SDA helped to understand the importance of energy and environmental implications of differential household consumption patterns.

The *first chapter* introduced the issues and the problems of climate change and the unsustainable consumption pattern at households as one of the major causes of climate change. The problem and objective of the study were also stated here. The *second chapter* was on differential household consumption patterns. Having the different consumption patterns among the households, this chapter helped to identify the groups or clusters of households with almost similar types of consumption patterns. *Chapter three* tried to get the energy intensity (energy embodied-ness) and related CO_2 emission intensity of the production sectors of the economy through applying the energy input-output analysis.

The *chapter four* estimated the direct energy requirements and related CO_2 emission. The sources of energy directly consumed in households are considered here. The *fifth chapter* was on to estimate the total energy requirement, direct and indirect taken together, and the related CO_2 emission (direct plus indirect). The *sixth chapter* discussed the structural decomposition analysis. Through this analysis, the partial effects of consumption patterns on CO_2 had been calculated and separated from the other factors through decomposition analysis. And the last chapter, the *seventh chapter* provided some concluding remarks. An overview of the study has been added. It has also tried to include the policy recommendations for policymakers. The shortcomings of the study would also be incorporated here.

7.2. Summary of Major Findings

In chapter 2, the study had investigated household consumption patterns. This study revealed that the percentage share of expenditure on food was decreasing continuously and steadily for all the time points since 1987-88 for rural and urban areas, both. The food expenditure share was 64 percent of total expenditure for rural households in 1987-88 and it has come down to 50.2 per cent of total expenditure in 2011-12. For the urban households, it was 56.4 per cent in 1987-88 and has come down to 41.1 per cent in 2011-12. This result validated the Engel’s theorem.

Moreover, the percentage share of all food items came down, except for the beverages and process foods. Among the non-food consumption items, the ‘fuels & lights’ was the most key component which had contributed a momentous change in consumption pattern. The percentage share of expenditure on fuels and lights had increased for all the three settlement categories. The ‘recreation & entertainment’ had got larger importance in Indian during the same study periods. Transportation was the consumption item whose share of expenditure had increased by a significant level and having a significantly higher level for all three areas. However, that share was highest for households in cities and lowest for households in the rural area. Similar patterns of expenditures had been seen for personal services.

This study applied the method of multidimensional scaling to understand the similarity or dissimilarity among the different household groups. The results of NSS 1993-94 consumption expenditure data revealed that the households were grouped into four major clusters by analyzing the proximity of the consumption pattern. The rural lower-income households stood very different than other types of households. The lower-income classes of city and town and the middle-income classes of the rural area had a similar pattern of consumption expenditure. The third cluster was with the households from middle-income classes of city and town, and higher-income classes of rural area. The last cluster was containing only the higher-income households of town and city.

The energy input-output analysis presented in Chapter 3 had revealed that the coal tar product sector was the most intense energy-consuming sector, for direct energy use in 1993-94. The next three direct energy-intense sectors were cement, fertilizers, and iron & steel. The coal tar product sectors still maintained its first rank in 2007-08 also. The non-ferrous basic metal sector became the second most intense sector in 2007-08. During the same time, the iron & steel sector became more direct energy-intense, but cement and fertilizer became less. Now, if we consider the total primary energy intensity, then the 'Other Transportation Equipment' sector stood first in absorbing total primary energy, 24.33 MJ/Rupee in 1993-94.

The 'Coal Tar Products' sector was at third in that line with 13.59 MJ/Rupee. Although the TPEI has come down to 13.35 MJ/Rupee in 2007-08, the Coal tar products sector stood first in that intensity. In the case of CO_2 emission, the Coal tar products, thermal electricity, and cement were to topmost polluters (direct) in 1993-94. In 2007-08, the non-ferrous basic metal, thermal electricity, and iron & steel were the top three polluters. One important aspect that, in almost all sectors, CO_2 emission intensity declined drastically. And there was a similar picture for the total CO_2 emission intensity.

The direct energy consumption and related CO_2 emission had been calculated in Chapter 4. It had been found that an average Indian household used almost 333.20 MJ of energy per capita per month in 1993-94. It is increased to 420.24 MJ of energy per capita per month in 2011-12. Firewood is predominantly the most important source of energy in Indian households. Out of the total direct energy consumption, 68 per cent was used to come from firewood in 1993-94; and there was a slight decline, it was almost 57 per cent in 2011-12. Though the percentage share of firewood had been declined, the energy consumption from firewood had increased from 226.18 MJ to 241.13 MJ per capita per month.

The other important sources of energy such as kerosene, dung cake, and coal had lost their importance over time, in the path of the energy transition. The electricity was the maximum gainer. During the same period, per capita monthly electricity consumption had increased from only 14.78 MJ (5 per cent of total direct energy consumption) to almost 50.88 MJ; it was almost three times the increase in direct energy consumption in an absolute sense. LPG and Petrol were the other important sources which were increased – LPG: from 4 per cent to 9 per cent and Petrol: 1 per cent to 4 per cent. In a sentence, the relative importance of so-called traditional sources of energy like firewood, dung cake, coal, and kerosene had declined, whereas that of modern sources of energy like electricity, LPG, petrol had increased. Still, firewood remains an exception.

Although the relative importance of firewood had gone down, the actual and direct energy usage in absolute terms has gone up. It reflected the crude picture of the Indian economy – how desperately an Indian household remained dependent on firewood. However, the settlement wise analysis revealed a detailed picture of it. Firewood consumption had increased only in a rural area, not in the city or town. Similar patterns had been observed for kerosene and dung cake. The usages of coal were comparatively more in town than rural and city, and it remained high in town in 2011-12. During the same time, the usages of electricity had increased to all sorts of households in India. The usages of LPG had also increased; however, it remained at a low level in a rural area compared to its urban counterparts.

The total energy consumption and related CO_2 emission by the Indian households had been estimated in Chapter 5. The study revealed that on average, an Indian household used to use 801.59 MJ of energy monthly per capita in 1993-94. However, the energy consumption had increased more than double (about 217 per cent increases) in 2011-12, which was about 2542 MJ (monthly per capita). However, the increase for non-energy items during the same period was less than double (86 per cent increase, only). On the other hand, the increase in energy items was about 317 per cent during the same period. However, the monthly per capita CO_2 emission had mixed results during the same periods. The monthly per capita CO_2 emission had increased by 18 per cent; from 60.28 kg in 1993-94 to 71.10 kg in 2011-12. In energy items, it was increased by 43 per cent over the period. And that was for the non-energy sector had decreased by 20 per cent over the same period.

The energy consumption from firewood and dung cake was at a very high level in 1993-94 in the rural area irrespective of the income classes, and even it became higher in 2011-12. The energy consumption from firewood and dung cake was at the highest level for higher-income class households in the rural area and still was at a higher level in 2011-12. As firewood and dung cake consumption is mostly a rural phenomenon, the consumption of coal and coke is mostly an urban phenomenon. In 1993-94, the urban areas, specifically towns, were the major user of coal and coke. The monthly per capita energy consumption and related CO_2 emission were both were high in all types of households in towns. However, over 18 years, it had declined significantly.

The energy consumption from kerosene had increased enormously during the same periods. Kerosene consumption was more in city households, however, it has declined many folds during the study period. It could be seen a highly skewed distribution of energy consumption from electricity in different types of households. The monthly per capita consumption level was extremely lower in households of clusters A and B. It was extremely high for the households in cluster D. whereas, it was moderately high for the households in cluster C.

The energy-related CO_2 emissions from electricity consumption across the different types of households had a similar scenario as in the case of electricity energy consumption. There was a huge difference in lower and higher ends of the consumption pattern structures (0.40 Kg for LIC in rural and 23.93 Kg for HIC in the city) in 1993-94. There was an increase in CO_2 emission from electricity consumption across all types of households from 1993-94 to 2011-12. The consumption pattern for LPG was almost similar to the electricity consumption pattern. The situation is still diverging; the incremental measure was just about 2.48 MJ in cluster A, the about more than 700 MJ in cluster D (higher end). The energy consumption from LPG had in increasing trend as moving from cluster A to cluster D for both the period. Similar to energy consumption, the energy-related CO_2 emission was skewed towards the cluster D (the higher end).

From the Chapter 6, it could be seen that almost all types of households had a large role in contributing to CO_2 emission due to the consumption of energy items. Specifically, for transitional sources of energy, the households in clusters A and B had a larger contribution. And for modern sources of energy, the households in clusters C and D had a larger contribution to CO_2 emission. For food items, the households in clusters C and D had played a crucial role in reducing CO_2 emission due to consumption, mainly of cereals, pulses, and vegetables. The households in cluster C and D had contributed larger CO_2 emissions due to an increase in the consumption of non-food items, mainly transportation, education, and medical care. The households in Cluster A and B, had a lesser role in contributing energy-related CO_2 emission.

7.3. Major Conclusions

Some of the major conclusions of this study are as:

i. The share of food expenditure to total expenditure had come down continuously over the study periods and that of non-food expenditure became more than 50 per cent of total household expenditure.

ii. The household consumption patterns were very different among different income classes and across different settlement categories. The consumption patterns of rural lower income households were very different than others. There was similarity between the consumption patterns of higher-income classes of towns and cities.

iii. Firewood is still predominantly the most important source of energy in Indian households. The uses of modern energy sources such as electricity, petrol and LPG had increased for all households. And coal, dung cake, and kerosene were the major losers – losing the ground.

iv. The energy-related CO_2 emission (on per capita basis) remained almost at same level for town and city households. But it increased significantly for rural households because of firewood consumption. The monthly per capita CO_2 emission for higher-income households declined, but there was an increase for middle- and lower-income households.

v. The overall energy intensities of the top energy-intense sectors of Indian economy had declined from 1993-94 to 2007-08. The energy-related CO_2 emission intensity for almost all sectors had also declined over the same period.

vi. The increase in total energy consumption due to energy sources had become more than doubled in an average Indian household between 1993-94 and 2011-12. However, for non-energy consumption items, the total energy consumption had increased, but less than double.

vii. The total energy consumption due to firewood and dung cake was high in rural higher-income households, and it is still at high level, Coke and coal use was mainly a town phenomenon in 1993-94, but it declined in 2011-12. The energy consumption from electricity and LPG had increased significantly, but not equally, to all types of households.

viii. The monthly per capita energy consumptions have increased for all food consumption bundle, except the beverages and processed foods. However, there was a significant fall of CO_2 emission for all good bundles and for all households over the study periods.

ix. For non-food consumption bundles, energy consumption had increased for all households. The increase was very high for transportation, housing and medical care. The energy consumption for almost all non-food consumption bundles were very high for all higher-income classes, mainly in towns and cities. The CO_2 emission had increased for about all non-food consumption bundles for all households.

x. With respect to effects of consumption pattern, households in clusters A and B (mainly, lower-income classes) had a larger contribution for transitional sources of energy. And for modern sources of energy, the households in clusters C and D (mainly higher- and middle-income classes and towns and cities) had a larger contribution to CO_2 emission.

xi. Households in higher- and middle-income classes and mainly in towns and cities, the change in consumption patterns of non-food consumption bundles had great influence on CO_2 emission, mainly transportation, education, and medical care.

7.4. Policy Recommendations

It is a well-established understanding, now, that the supply side management is not sufficient to fight against climate change. Managing the demand side factors is also equally important. Agenda 21 of the Rio Summit directed the global community for reducing unsustainable consumption to reduce GHGs. It had also directed the policymakers of the different countries to find a way for sustainable consumption. Since the beginning, Indian policymakers have tried to control the production sectors as it is easier to find the targets. Since the 1980s, the household study had started getting importance in academia. However, there were hardly any policies for regulating household consumption patterns.

- This study may help policymakers to devise suitable policy instruments to change the household consumption pattern in a desirable direction as aspired by society. The carrot and stick policy can be suitable here. Any less polluting sources of energy should be encouraged by subsidization policies. By making the less polluting consumption items accessible and affordable to the households, any policy maker can encourage the consumption of less CO_2 emitting items. Imposition of tax or increasing the tax rate on the consumption of more CO_2 emitting household items can discourage the consumption, ultimately, through the substitution and income effects. This study may help the policy makers to design the right instruments for controlling household consumption.

- The policy makers can target the consumption items, efficiently and confidently, if they know the intensity of energy consumption and CO_2 emission of every items. This study has identified the most polluting consumption items and the production sectors through which the households consume the energy intensively. It may help to control those polluting sectors on the production side also by inventing any policy to substitute those highly polluting sectors. Policymakers can get an understanding of the household consumption items through which they can control those highly energy-intense consumption items.
- This study also provides the household analysis, separated into different settlement categories, such as rural, town, and city. Therefore, this type of analysis definitely will help the policymakers to the target a specific group of households with more unsustainable consumption patterns. Any policy designed for a specific type of households (or different policy for different types of households) may provide more efficient outcomes. This present study may help the policy makers to identify and design the energy policy for the households which follow unsustainable consumption patterns, intensively and also help to identify the unsustainable consumption items.

7.5. Limitations of the Study

The present study showed with the considerable conviction that the differential household consumption patterns had an immense implication on energy consumption and related CO_2 emission. However, although this work attempted a holistic presentation of fact, still this study carries many assumptions to frame the real economy into the economic model. Although the result of the study has great implications for the field of energy economics and in policy perspectives, the study has some limitations.

a. The two major sources of data were NSSO and CSO. The NSSO surveys consumption expenditure every year, and the same with large sample data every five years. This study has used the large sample data; and NSSO had conducted a large sample survey on consumption expenditure in 2011-12. Since then there was the publication of survey data with a large sample survey. On the other hand, CSO publishes input-output transition tables almost five-years interval. And the last input-output transaction tables were published by the CSO was for 2007-08. Therefore, the latest data used for consumption expenditure was of 2011-12, and of input-output data of aggregated sectors of the economy was of 2007-08. Not having recent data from NSSO and CSO is the limitation of this thesis.

b. There are issues related to energy conversion factors and CO_2 emission factors. In 1993-94, there were only global factors available. IPCC prepared those energy conversion factors and CO_2 emission factors for every source of energy – common factors. There were no India-specific factors available at that time. In this study, the global common factors were used for the analysis for 1993-94. However, for the year 2011-12, India-specific energy conversion factors and CO_2 emission factors were used.

c. There were issues related to aggregation. Every time we make an aggregate, we would lose much information. The input-output transaction tables are such an example of aggregation. The whole economy is classified into a few aggregated sectors, for example, 130 sectors for 2007-08. If we look at details of industry classification, there are some differentiable sub-sectors within each aggregated sector. The energy intensity and CO_2 emission intensity calculated for each aggregated sectors were used for all sub-sectors within it.

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APPENDICES

Table 3A - Concordance between IOTTs in 1993-94 and 2007-08 and rearranging into 111 sectors			
Code of the Sectors for this Thesis	Name of the Sectors	Sectors in IOTTs in 1993-94	Sectors in IOTTs in 2007-08
1	Paddy	001	001
2	Wheat	002	002
3	Jowar	003	003
4	Bajra	004	004
5	maize	005	005
6	Gram and Pulses	006, 007	006, 007
7	Sugarcane	008	008
8	Groundnut	009	009
9	Jute	010	012
10	Cotton	011	013
11	tea	012	014
12	Coffee	013	015
13	Rubber	014	016
14	Coconut	015	010
15	Tobacco	016	017
16	Other Crops	017	011, 018, 019, 020
17	Milk & Milk Product	018	021
18	Animal Services	019	022
19	Other Livestock & Fishing	020, 022, 101	023, 024, 026
20	Forestry & Logging	021	025
21	Coal & Lignite	023	027
22	Crude Petroleum , Natural gas	024	028, 029
23	Iron Ore	025	030
24	Manganese ore	026	031
25	Bauxite	027	032
26	Copper ore	028	033
27	Other metallic minerals	029	034

Table 3A - Concordance between IOTTs in 1993-94 and 2007-08 and rearranging into 111 sectors			
Code of the Sectors for this Thesis	Name of the Sectors	Sectors in IOTTs in 1993-94	Sectors in IOTTs in 2007-08
28	Lime stone	030	035
29	Mica	031	036
30	Other non-metallic minerals	032	037
31	Sugar	033	038
32	Khandsari, boora	034	039
33	Hydrogenated oil (vanaspati)	035	040
34	Edible oils other	036	041
35	Tea and coffee processing	037	042
36	Miscellaneous food products	038	043
37	Beverages	039	044
38	Tobacco products	040	045
39	Khadi, cotton textiles in Handlooms	041	046
40	Cotton textiles	042	047
41	Woollen textiles	043	048
42	Silk textiles	044	049
43	Art silk, synthetic	045	050
44	Jute, hemp, Mesta textiles	046	051
45	Carpet weaving	047	052
46	Readymade garments	048	053
47	Miscellaneous textile products	049	054
48	Furniture and fixtures-wooden	050	055
49	Wood and wood products except furniture	051	056
50	Paper, paper products and newsprint	052	057
51	Printing, publishing and allied activities	053	058
52	Leather footwear	054	059
53	Leather and leather products except footwear	055	060
54	Rubber products	056	061
55	Plastic products	057	062
56	Petroleum products	058	063
57	Coal tar products	059	064
58	Inorganic heavy chemicals	060	065
59	Organic heavy chemicals	061	066
60	Fertilizers	062	067
61	Pesticides	063	068
62	Paints, varnishes and lacquers	064	069

Table 3A - Concordance between IOTTs in 1993-94 and 2007-08 and rearranging into 111 sectors			
Code of the Sectors for this Thesis	Name of the Sectors	Sectors in IOTTs in 1993-94	Sectors in IOTTs in 2007-08
63	Drugs and medicines	065	070
64	Soaps, cosmetics, glycerine	066	071
65	Synthetic fibres, resin	067	067
66	Other chemicals	068	073
67	Structural clay products	069	074
68	Cement	070	075
69	Other non-metallic mineral products	071	076
70	Iron and steel Ferro alloys	072	077
71	Iron and steel casting and forging	073	078
72	Iron and steel foundries	074	079
73	Non-ferrous basic metals	075	080
74	Hand tools, hardware	076	081
75	Miscellaneous metal products	077	082
76	Tractors and other agricultural implements	078	083
77	Industrial machinery for food and textile industries	079	084
78	Industrial machinery (except food and textile)	080	085
79	Machine tools	081	086
81	Other non-electrical machinery	083	087
82	Electrical industrial machinery; Electrical cables, wires	084, 085	088, 089
83	Batteries	086	090
84	Electrical appliances	087	091
85	Communication equipment	088	092
86	Other electrical machinery	089	093
87	Electronic equipment including TV	090	094
88	Ships and boats	091	095
89	Rail equipment	092	096
90	Motor vehicles	093	097
91	Motor cycles and scooters	094	098
92	Bicycles, cycle-rickshaw	095	099
93	Other transport equipment	096	100
94	Watches and clocks	097	101
95	Miscellaneous manufacturing	098, 82	102, 103, 104, 105
96	Construction	099	106
97	Electricity	100	107

Table 3A - Concordance between IOTTs in 1993-94 and 2007-08 and rearranging into 111 sectors			
Code of the Sectors for this Thesis	Name of the Sectors	Sectors in IOTTs in 1993-94	Sectors in IOTTs in 2007-08
98	Water supply	102	108
99	Railway transport services	103	109
100	Other transport services	104	110, 111, 112, 113
101	Storage and warehousing	105	114
102	Communication	106	115
103	Trade	107	116
104	Hotels and restaurants	108	117
105	Banking	109	118
106	Insurance	110	119
107	Ownership of dwellings	111	120
108	Education and research	112	121
109	Medical and health	113	122
110	Other services	114	123, 124, 125, 126, 127, 128, 129
111	Public administration and defence	115	130

Table 3B – Direct and Total Primary Energy Intensity in India					
	Aggregate Sectors	Direct		Total	
		1993-94	2007-08	1993-94	2007-08
1	Coal & Lignite	**0.0085**	**0.0117**	**1.0492**	**1.0295**
2	Natural Gas	**0.0179**	**0.0005**	**1.1974**	**1.0120**
3	Crude Oil	**0.0007**	**0.0003**	**1.0061**	**1.0031**
4	Petroleum Products	**0.6074**	**6.3821**	**0.6317**	**6.7620**
5	Thermal Electricity	**3.3979**	**1.3524**	**4.7767**	**2.4062**
6	Hydro & Nuclear Electricity	**0.0525**	**0.0343**	**1.9768**	**1.4231**
7	Paddy	0.0118	0.0181	0.9709	1.4643
8	Wheat	0.0366	0.0235	1.5443	1.4367
9	Jowar	0.0016	0.0089	0.5829	2.4537
10	Bajra	0.0068	0.0151	0.6973	1.6093
11	Maize	0.0139	0.0203	0.7695	1.8310
12	Gram & Pulses	0.0078	0.0047	0.6137	1.0087
13	Sugarcane	0.0080	0.0145	0.4135	1.0376
14	Groundnut	0.0025	0.0052	0.6615	0.9052
15	Coconut	0.0000	0.0000	0.3003	0.5450
16	Jute	0.0000	0.0000	0.1659	0.9452
17	Cotton	0.0106	0.0139	0.6159	1.1166
18	Tea	0.0000	0.0000	0.1420	0.3274
19	Coffee	0.0000	0.0000	0.2262	0.5236
20	Rubber	0.0000	0.0000	0.2764	1.0347
21	Tobacco	0.0045	0.0304	0.4387	1.8943
22	Other Crops	0.0086	0.0068	0.5412	0.8307
23	Milk and Milk Products	0.0000	0.0000	0.1531	0.2336
24	Animal Services (Agri.)	0.0000	0.0000	0.6588	1.1553
25	Other Livestock & Fishing	0.0002	0.0000	0.2702	0.6036
26	Forestry and Logging	0.0004	0.0007	0.2094	0.4851
27	Iron Ore	0.0329	0.1541	1.9910	3.4770
28	Manganese Ore	0.0009	0.0164	0.3505	0.3808
29	Bauxite	0.0024	0.0781	0.4149	0.8594
30	Copper Ore	0.0607	0.0306	1.4968	1.4237
31	Other Metallic Minerals	0.0630	0.0779	1.3185	2.1330
32	Lime Stone	0.0239	0.0167	0.9652	0.5831
33	Mica	0.0000	0.0182	7.5406	0.7213
34	Other Non-metallic Minerals	0.0066	0.0044	0.3755	0.3071
35	Sugar	0.1510	0.0097	0.7369	0.8339
36	Khandsari, Boora	0.0487	0.0120	0.8696	0.9201
37	Hydrogenated Oil (Vanaspati)	0.3079	0.0255	1.7189	0.7726
38	Edible Oils Other Than Vanaspati	0.1387	0.0289	1.0201	0.8708
39	Tea and Coffee Processing	0.5920	0.0678	1.4917	1.7647
40	Misc. Food Products	0.1473	0.0383	0.9318	1.1406
41	Beverages	0.4729	0.0685	1.5102	1.8420
42	Tobacco Products	0.0315	0.0367	0.8916	0.9309

Table 3B – Direct and Total Primary Energy Intensity in India					
Aggregate Sectors		Direct		Total	
		1993-94	2007-08	1993-94	2007-08
43	Khadi, Cotton Textiles (Handlooms)	0.0239	0.0247	1.0493	0.5737
44	Cotton Textiles	0.1885	0.0596	1.6166	1.4863
45	Woolen Textiles	0.3248	0.0539	1.6341	1.2770
46	Silk Textiles	0.0956	0.1205	1.0609	1.9983
47	Art Silk, Synthetic Fiber Textiles	0.2376	0.1166	2.0408	1.8106
48	Jute, Hemp, Mesta Textiles	0.3074	0.2148	1.6910	1.4720
49	Carpet Weaving	0.1982	0.0739	1.2644	0.8627
50	Readymade Garments	0.0267	0.0389	1.1762	1.2314
51	Misc. Textile Products	0.1249	0.1684	1.4180	1.7486
52	Furniture and Fixtures - Wooden	0.0188	0.0816	0.6276	1.3635
53	Wood and Wood Products	0.0796	0.1771	0.7117	1.1448
54	Paper, Paper Prods. & Newsprint	2.0452	0.5936	4.3663	2.5075
55	Printing and Publishing	0.0309	0.0956	1.8560	2.3731
56	Leather Footwear	0.0252	0.0062	1.0016	0.8330
57	Leather and Leather Products	0.0513	0.0061	0.9951	0.8114
58	Rubber Products	0.4572	0.0611	2.2400	1.5765
59	Plastic Products	0.2641	0.0652	2.3853	2.0661
60	Coal Tar Products	12.5368	11.4647	14.2090	13.3548
61	Inorganic Heavy Chemicals	2.0738	1.0240	4.2084	4.6292
62	Organic Heavy Chemicals	1.2410	3.0437	3.6141	5.7023
63	Fertilizers	3.3506	2.7394	5.8543	7.7709
64	Pesticides	0.1408	0.1204	2.5931	1.7483
65	Paints, Varnishes and Lacquers	0.7190	0.2984	3.0561	2.0112
66	Drugs and Medicines	0.3036	0.1374	1.9085	3.9802
67	Soaps, Cosmetics & Glycerin	0.1414	0.0793	2.4356	2.9836
68	Synthetic Fibers, Resin	1.5229	0.4480	3.6602	2.6805
69	Other Chemicals	0.9038	0.6710	2.7316	2.3147
70	Structural Clay Products	2.4180	0.6530	3.8572	3.5824
71	Cement	4.3255	3.5667	6.4169	6.2559
72	Other Non-metallic Mineral Prods.	1.0299	0.6424	2.6891	4.1163
73	Iron, Steel and Ferro Alloys	2.6523	4.8340	5.9725	8.6932
74	Iron and Steel Casting & Forging	1.1320	2.6508	4.9307	6.9684
75	Iron and Steel Foundries	0.4560	1.9276	4.2693	6.1685
76	Non-ferrous Basic Metals	0.7275	5.4880	3.5626	9.9344
77	Hand Tools, Hardware	0.4977	0.1198	2.9184	2.7279
78	Misc. Metal Products	0.3619	1.2249	3.1721	3.6752
79	Tractors and Agri. Implements	0.2561	0.0739	2.7270	2.2120
80	Industrial Machinery (F & T)	0.2247	0.1058	2.1582	4.0832
81	Industrial Machinery (others)	0.1580	0.0464	2.5927	2.1877
82	Machine Tools	0.1943	0.0655	2.8616	2.2201
83	Other Non-electrical Machinery	0.1313	0.0731	2.3229	2.2466
84	Electr. Indust. Machin. & Wire & Cablles	0.0997	0.0406	2.2334	2.7990
85	Batteries	0.2728	0.0332	2.2974	2.3205

Table 3B – Direct and Total Primary Energy Intensity in India					
Aggregate Sectors		Direct		Total	
		1993-94	2007-08	1993-94	2007-08
86	Electrical Appliances	0.1360	0.0164	2.0412	0.9254
87	Communication Equipment	0.0892	0.0112	2.0017	0.7199
88	Other Electrical Machinery	0.1570	0.9442	1.9497	3.9764
89	Electronic Equipments (incl.TV)	0.0219	0.0133	1.9650	1.2825
90	Ships and Boats	0.0149	0.0025	1.8052	1.3280
91	Rail Equipments	0.1394	0.1662	2.1325	1.9778
92	Motor Vehicles & Motor Cycles	0.4246	0.0260	15.1167	2.1176
93	Bicycles, Cycle-rickshaw	0.0267	0.1159	13.5881	2.6657
94	Other Transport Equipments	0.0449	0.0153	24.3267	1.7852
95	Watches and Clocks	0.0344	0.0082	1.8983	0.7824
96	Misc. Manufacturing	0.2921	0.0637	2.2538	1.6629
97	Construction	0.0211	0.0085	1.8641	2.0228
98	Water Supply	0.0495	0.0217	1.4727	1.2526
99	Railway Transport Services	1.2225	0.1026	2.4804	1.6524
100	Other Transport Services	0.0412	0.0050	2.0559	4.1929
101	Storage and Warehousing	0.0682	0.1165	1.4038	1.7043
102	Communication	0.0219	0.0143	3.2607	0.8072
103	Trade	0.0301	0.0278	0.5895	0.6784
104	Hotels and Restaurants	0.4586	0.0165	1.0793	0.9663
105	Banking	0.0057	0.0093	0.2623	0.3395
106	Insurance	0.0098	0.0131	0.4664	0.6395
107	Ownership of Dwellings	0.0000	0.0000	0.1082	0.0925
108	Education and Research	0.0054	0.0006	0.2722	0.2393
109	Medical and Health	0.0031	0.0018	0.9008	0.8527
110	Other Services	0.3888	0.0146	1.5510	0.4280
111	Public Administration	0.0000	0.0000	0.0016	0.0000

Source: Author's Calculation

Table 3C - Direct and Total CO2 Emission Intensity in Indian Production Sectors					
Aggregated Sectors		Direct		Total	
		1993-94	2007-08	1993-94	2007-08
1	Coal & Lignite	0.01169	0.01204	1.03807	1.01763
2	Natural Gas	0.00220	0.00085	1.00875	1.00903
3	Crude Oil	0.00475	0.00569	1.01500	1.05127
4	Petroleum Products	0.06062	0.16051	1.07115	1.20454
5	Thermal Electricity	69.59442	52.28743	91.93409	65.18484
6	Hydro & Nuclear Electricity	0.00000	0.00000	20.08848	11.55000
7	Paddy	0.73210	0.26206	6.44908	3.81554
8	Wheat	0.77793	0.22884	10.19486	3.90142
9	Jowar	1.36271	0.67565	4.34639	5.09998
10	Bajra	1.88183	0.74149	5.47494	3.37425
11	Maize	0.61577	0.44805	5.23731	4.19229
12	Gram & Pulses	0.58287	0.28496	4.43845	2.17714
13	Sugarcane	0.18634	0.12323	2.66902	2.58413
14	Groundnut	0.71816	0.24872	4.47581	1.91534
15	Coconut	0.00000	0.10142	1.77314	1.20753
16	Jute	0.00000	0.22061	1.12486	1.82703
17	Cotton	0.45887	0.18859	4.23164	2.66996
18	Tea	0.00000	0.06180	0.88450	0.64132
19	Coffee	0.00000	0.07606	1.72382	1.42088
20	Rubber	0.00000	0.07322	1.65453	2.49106
21	Tobacco	0.31261	0.19426	2.78030	4.79850
22	Other Crops	0.43435	0.23818	3.66014	1.95588
23	Milk and Milk Products	0.00000	0.00000	1.11801	0.57282
24	Animal Services (Agri.)	0.00000	0.00000	4.79050	2.75779
25	Other Livestocks & Fishing	0.50956	0.11544	2.23829	1.47556
26	Forestry and Logging	0.67281	0.24541	1.89099	1.07972
27	Iron Ore	4.62716	3.08546	12.72116	11.43855
28	Manganese Ore	0.90167	0.12940	2.23218	1.46047
29	Bauxite	0.92041	0.90558	3.43057	3.19551
30	Copper Ore	2.88875	0.63907	12.08028	4.42334
31	Other Metallic Minerals	1.57029	0.83180	10.23883	8.19320
32	Lime Stone	2.51575	0.31308	8.09655	1.93004
33	Mica	10.32149	0.44175	23.91103	1.92732
34	Other Non-metallic Minerals	0.97832	0.13246	3.19581	0.91901
35	Sugar	1.50274	0.27178	5.41264	2.15999
36	Khandsari, Boora	1.84153	0.25732	7.05235	2.45397
37	Hydrogenated Oil (Vanaspati)	2.83152	0.23385	13.32517	2.30104
38	Edible Oils Other Than Vanaspati	1.40226	0.28134	7.70775	2.49392
39	Tea and Coffee Processing	4.47748	0.48150	11.63155	4.83405
40	Misc. Food Products	1.87739	0.33678	7.31941	3.48539
41	Beverages	4.58276	0.62699	12.48482	5.72157

Table 3C - Direct and Total CO2 Emission Intensity in Indian Production Sectors					
Aggregated Sectors		Direct		Total	
		1993-94	2007-08	1993-94	2007-08
42	Tobacco Products	0.60457	0.40801	7.09931	2.93796
43	Khadi, Cotton Textiles (Handlooms)	0.32570	0.22176	8.05278	1.83825
44	Cotton Textiles	1.84453	0.51309	12.59146	4.50880
45	Woolen Textiles	3.49234	0.49177	13.09558	4.14531
46	Silk Textiles	1.23687	0.90790	8.47772	5.82680
47	Art Silk, Synthetic Fiber Textiles	2.09480	1.19256	15.29584	5.40862
48	Jute, Hemp, Mesta Textiles	2.95556	1.76262	13.79061	6.26576
49	Carpet Weaving	2.11559	0.54470	10.09524	3.16192
50	Readymade Garments	0.41483	0.34931	9.07762	3.94610
51	Misc. Textile Products	1.05204	1.14843	10.68860	5.89439
52	Furniture and Fixtures - Wooden	0.46880	0.86502	4.98563	5.51924
53	Wood and Wood Products	1.03503	1.77520	5.78682	4.44688
54	Paper, Paper Prods. & Newsprint	19.39360	5.96194	37.89967	12.25140
55	Printing and Publishing	0.48976	0.99280	15.35152	9.54103
56	Leather Footwear	0.48508	0.09225	7.69725	2.34669
57	Leather and Leather Products	0.68982	0.08315	7.71583	2.47184
58	Rubber Products	3.66313	0.57367	16.21056	5.62966
59	Plastic Products	1.56728	0.56678	15.86216	6.10451
60	Coal Tar Products	89.82567	39.93723	101.54269	44.31880
61	Inorganic Heavy Chemicals	17.46161	6.78070	32.49607	14.57223
62	Organic Heavy Chemicals	7.80140	3.21010	24.78136	9.00175
63	Fertilizers	14.19404	6.93185	28.96161	15.67314
64	Pesticides	1.77691	1.09724	19.48575	5.53528
65	Paints, Varnishes and Lacquers	4.86913	1.67096	21.54288	6.20980
66	Drugs and Medicines	2.24080	1.08815	13.84984	9.66043
67	Soaps, Cosmetics & Glycerin	1.47550	0.92666	18.71588	8.64684
68	Synthetic Fibers, Resin	8.81287	1.34050	23.25957	5.92100
69	Other Chemicals	7.23970	2.17186	20.66989	7.09893
70	Structural Clay Products	24.53056	7.44214	34.68576	13.37028
71	Cement	40.84277	33.37021	56.83335	39.41901
72	Other Non-metallic Mineral Prods.	13.31530	7.31420	24.09918	17.12065
73	Iron, Steel and Ferro Alloys	25.58522	45.04912	51.86939	67.14294
74	Iron and Steel Casting & Forging	10.70688	25.69557	41.53511	51.42057
75	Iron and Steel Foundries	4.43526	17.95014	35.71677	45.47445
76	Non-ferrous Basic Metals	6.79668	53.54908	28.41523	80.58683
77	Hand Tools, Hardware	5.62115	1.29887	24.27711	18.16536
78	Misc. Metal Products	3.50285	11.47491	25.95768	27.42062
79	Tractors and Agri. Implements	2.53700	0.63825	20.90203	14.94904
80	Industrial Machinery (F & T)	2.38562	0.70144	16.82925	27.63670
81	Industrial Machinery (others)	1.36416	0.30012	20.41836	14.43919
82	Machine Tools	1.89121	0.60522	23.09012	14.10414

Table 3C - Direct and Total CO2 Emission Intensity in Indian Production Sectors					
Aggregated Sectors		Direct		Total	
		1993-94	2007-08	1993-94	2007-08
83	Other Non-electrical Machinery	1.54159	0.59690	18.58794	15.17363
84	Electr. Indust. Machin. & Wire & Cablles	1.10193	0.36454	17.35530	18.20356
85	Batteries	2.20803	0.13397	17.08381	14.02504
86	Electrical Appliances	1.86780	0.16123	16.03390	5.49779
87	Communication Equipments	1.01280	0.06655	15.46243	4.24426
88	Other Electrical Machinery	1.43445	9.23484	14.93212	27.39483
89	Electronic Equipments (incl.TV)	0.54318	0.07188	14.62885	7.59834
90	Ships and Boats	0.21659	0.02842	13.93743	8.09304
91	Rail Equipments	1.56193	1.74263	17.74619	11.90926
92	Motor Vehicles & Motor Cycles	12.41633	0.17436	21.27588	13.15686
93	Bicycles, Cycle-rickshaw	1.30747	1.16034	31.21019	16.13814
94	Other Transport Equipments	1.02222	0.09523	47.68864	10.57242
95	Watches and Clocks	1.02416	0.02476	14.73883	3.01825
96	Misc. Manufacturing	1.91963	0.60857	15.65535	7.73353
97	Construction	0.15346	0.19551	15.01585	10.49741
98	Water Supply	0.51134	0.07634	9.47420	3.89031
99	Railway Transport Services	12.37520	0.66345	21.22827	8.06573
100	Other Transport Services	9.27728	3.83672	18.29091	7.08432
101	Storage and Warehousing	0.43554	0.17167	10.19867	8.19652
102	Communication	0.23022	0.24060	7.94383	3.43606
103	Trade	0.27355	0.32218	4.33963	2.11904
104	Hotels and Restaurants	4.43526	0.20280	9.07098	2.96217
105	Banking	0.05583	0.06013	1.63454	1.28576
106	Insurance	0.48607	0.17609	3.16543	2.18777
107	Ownership of Dwellings	0.00000	0.00000	0.83824	0.47657
108	Education and Research	0.10403	0.02713	1.92811	0.59586
109	Medical and Health	0.22981	0.08292	6.77305	2.28739
110	Other Services	2.79487	0.01345	10.96989	2.02311
111	Public Administration	0.00000	0.00000	0.00230	0.00000

Source: Author's Calculation

Table 4A – Monthly Per Capita Direct Energy Use (MJ) by Rural Households								
Energy Items	1993-94				2011-12			
	HIC	MIC	LIC	Total	HIC	MIC	LIC	Total
				Rural				
Coke	5.017	2.806	1.825	3.052	0.994	1.786	2.143	1.699
Firewood	355.265	262.959	201.973	269.393	319.850	321.027	259.530	308.501
Electricity	19.879	6.372	1.968	8.179	66.805	28.566	11.696	32.845
Dung Cake	50.084	36.484	27.790	37.488	51.569	47.656	42.948	47.498
Kerosene	36.497	23.968	16.525	25.001	18.723	20.666	17.746	19.694
Coal	6.390	3.977	1.696	4.014	3.671	5.768	5.245	5.244
LPG	8.950	0.597	0.037	2.129	56.888	11.242	0.812	18.291
Charcoal	0.707	0.192	0.054	0.267	0.409	0.362	0.025	0.304
Candle	0.318	0.081	0.019	0.116	0.856	0.423	0.191	0.463
Gas	0.804	0.118	0.054	0.240	1.070	0.117	0.006	0.285
Petrol	5.987	0.344	0.009	1.387	39.513	5.817	0.462	11.489
Diesel	0.974	0.091	0.002	0.247	6.790	0.690	0.260	1.824
Other Fuels	1.388	1.400	1.206	1.360	0.669	0.769	0.666	0.728
Lubricants	0.085	0.005	0.000	0.020	0.290	0.039	0.003	0.082
All Energy	**492.346**	**339.393**	**253.157**	**352.893**	**568.097**	**444.928**	**341.732**	**448.948**

Source: Author's Calculation

Table 4B – Monthly Per Capita Direct Energy Use (MJ) by Town Households								
Energy Items	1993-94				2011-12			
	HIC	MIC	LIC	Total	HIC	MIC	LIC	Total
				Town				
Coke	6.610	9.116	6.143	8.067	0.159	2.869	8.599	3.761
Firewood	53.274	116.741	151.433	114.477	27.094	82.646	162.044	92.055
Electricity	64.391	27.648	9.137	29.306	189.873	80.094	33.154	87.183
Dung Cake	6.151	13.229	15.671	12.661	1.938	8.243	19.111	9.745
Kerosene	51.230	51.371	30.751	46.791	9.082	15.465	17.759	14.951
Coal	14.724	22.034	16.659	19.702	2.039	9.956	19.513	10.886
LPG	94.725	31.260	2.907	34.924	145.253	94.059	31.532	87.874
Charcoal	1.404	1.768	0.320	1.391	0.416	0.627	0.388	0.536
Candle	0.749	0.256	0.086	0.296	1.117	0.858	0.440	0.803
Gas	0.597	0.286	0.104	0.295	0.056	0.019	0.015	0.024
Petrol	37.725	4.559	0.116	8.767	136.994	26.370	3.012	39.106
Diesel	1.932	0.113	0.004	0.373	22.892	1.651	0.369	4.845
Other Fuels	0.931	0.923	0.887	0.916	0.850	0.331	0.264	0.400
Lubricants	0.518	0.055	0.001	0.116	1.141	0.179	0.021	0.300
All Energy	**334.961**	**279.359**	**234.220**	**278.083**	**538.903**	**323.368**	**296.220**	**352.471**

Source: Author's Calculation

Table 4C – Monthly Per Capita Direct Energy Use (MJ) by City Households								
Energy Items	1993-94				2011-12			
	HIC	MIC	LIC	Total	HIC	MIC	LIC	Total
City								
Coke	1.225	4.021	3.368	2.979	0.226	2.035	1.054	1.169
Firewood	5.790	26.531	70.270	23.178	3.667	19.314	78.502	13.665
Electricity	95.788	36.351	12.725	55.120	182.473	72.845	27.108	122.465
Dung Cake	1.706	3.358	3.208	2.764	0.529	9.874	14.828	5.673
Kerosene	48.260	88.846	66.497	72.564	9.769	19.830	11.401	14.932
Coal	3.927	6.474	6.451	5.576	0.411	2.564	11.310	1.803
LPG	119.405	43.051	6.805	66.631	126.545	89.203	28.450	104.875
Charcoal	0.067	0.248	0.000	0.162	0.095	0.080	0.000	0.085
Candle	0.555	0.234	0.119	0.337	0.845	0.762	0.723	0.800
Gas	0.314	0.217	0.000	0.231	0.000	0.000	0.000	0.000
Petrol	59.976	7.249	0.018	25.135	106.793	18.951	0.321	59.201
Diesel	2.140	0.065	0.000	0.789	21.877	0.939	0.000	10.628
Other Fuels	0.344	0.564	1.481	0.569	0.998	0.209	0.068	0.572
Lubricants	0.418	0.071	0.000	0.186	0.786	0.074	0.000	0.402
All Energy	**339.913**	**217.280**	**170.941**	**256.221**	**455.015**	**236.678**	**173.764**	**336.270**

Source: Author's Calculation

Table 4D – Monthly Per Capita Direct CO2 Emission (Kg) by Rural Households								
Energy Items	1993-94				2011-12			
	HIC	MIC	LIC	Total	HIC	MIC	LIC	Total
Rural								
Coke	0.543	0.304	0.197	0.330	0.106	0.191	0.229	0.182
Firewood	39.790	29.451	22.621	30.172	35.823	35.955	29.067	34.552
Dung Cake	5.008	3.648	2.779	3.749	5.157	4.766	4.295	4.750
Kerosene	2.623	1.722	1.188	1.797	1.346	1.486	1.276	1.416
Coal	0.604	0.376	0.160	0.380	0.347	0.546	0.496	0.496
LPG	0.564	0.038	0.002	0.134	3.590	0.709	0.051	1.154
Charcoal	0.079	0.022	0.006	0.030	0.046	0.041	0.003	0.034
Candle	0.023	0.006	0.001	0.008	0.063	0.031	0.014	0.034
Gas	0.043	0.006	0.002	0.013	0.058	0.006	0.000	0.016
Petrol	0.415	0.024	0.001	0.096	2.738	0.403	0.032	0.796
Diesel	0.072	0.007	0.000	0.018	0.503	0.051	0.019	0.135
Other Fuels	0.106	0.107	0.093	0.104	0.052	0.060	0.052	0.056
Lubricants	0.006	0.000	0.000	0.001	0.021	0.003	0.000	0.006
All Energy	**49.877**	**35.712**	**27.052**	**36.833**	**49.851**	**44.247**	**35.535**	**43.627**

Source: Author's Calculation

Table 4E – Monthly Per Capita Direct CO2 Emission (Kg) by Town Households								
Energy Items	1993-94				2011-12			
	HIC	MIC	LIC	Total	HIC	MIC	LIC	Total
Town								
Coke	0.715	0.986	0.664	0.873	0.017	0.307	0.920	0.402
Firewood	5.967	13.075	16.960	12.821	3.035	9.256	18.149	10.310
Dung Cake	0.615	1.323	1.567	1.266	0.194	0.824	1.911	0.974
Kerosene	3.682	3.692	2.210	3.363	0.653	1.112	1.277	1.075
Coal	1.393	2.084	1.576	1.864	0.193	0.942	1.846	1.030
LPG	5.974	1.971	0.183	2.203	9.165	5.935	1.990	5.545
Charcoal	0.157	0.198	0.036	0.156	0.047	0.070	0.043	0.060
Candle	0.055	0.019	0.006	0.022	0.082	0.063	0.032	0.059
Gas	0.027	0.013	0.005	0.013	0.003	0.001	0.001	0.001
Petrol	2.614	0.316	0.008	0.608	9.494	1.827	0.209	2.710
Diesel	0.143	0.008	0.000	0.028	1.696	0.122	0.027	0.359
Other Fuels	0.071	0.071	0.068	0.070	0.066	0.026	0.020	0.031
Lubricants	0.038	0.004	0.000	0.008	0.084	0.013	0.002	0.022
All Energy	**21.450**	**23.761**	**23.285**	**23.294**	**24.728**	**20.499**	**26.427**	**22.579**

Source: Author's Calculation

Table 4F – Monthly Per Capita Direct CO2 Emission (Kg) by City Households								
Energy Items	1993-94				2011-12			
	HIC	MIC	LIC	Total	HIC	MIC	LIC	Total
City								
Coke	0.132	0.435	0.364	0.322	0.024	0.218	0.113	0.125
Firewood	0.648	2.971	7.870	2.596	0.411	2.163	8.792	1.530
Dung Cake	0.171	0.336	0.321	0.276	0.053	0.987	1.483	0.567
Kerosene	3.468	6.385	4.779	5.215	0.702	1.426	0.820	1.074
Coal	0.371	0.612	0.610	0.528	0.039	0.243	1.070	0.171
LPG	7.530	2.715	0.429	4.202	7.985	5.629	1.795	6.618
Charcoal	0.007	0.028	0.000	0.018	0.011	0.009	0.000	0.009
Candle	0.041	0.017	0.009	0.025	0.062	0.056	0.053	0.059
Gas	0.015	0.010	0.000	0.011	0.000	0.000	0.000	0.000
Petrol	4.156	0.502	0.001	1.742	7.401	1.313	0.022	4.103
Diesel	0.159	0.005	0.000	0.058	1.621	0.070	0.000	0.788
Other Fuels	0.026	0.042	0.111	0.043	0.077	0.016	0.005	0.044
Lubricants	0.031	0.005	0.000	0.014	0.058	0.005	0.000	0.029
All Energy	**16.756**	**14.064**	**14.495**	**15.050**	**18.443**	**12.135**	**14.153**	**15.117**

Source: Author's Calculation

Table 5A – Concordance between 21 Aggregated Consumption Bundles and NSSO Consumptions Groups

	21 Groups	Name of the Groups	NSSO Consumptions Groups
Food Items	1	Food: Cereals, Pulses, Vegetables	Cereals, Cereal Substitutes, Gram & Pulses, and Vegetables
	2	Food: Milks, Egg, Fish, Meats	Milk & Milk Products, Egg, Fish, and Meat
	3	Food: Others	Sugar, Salt, Edible Oil, Spices
	4	Fruits	Fruits (Fresh), Fruits (Dry)
	5	Beverages & Processed Foods	Beverages & Processed Foods
	6	Pan, Tobacco & Intoxicants	Pan, Tobacco & Intoxicants
Non-Food Items	7	Clothing & Footwear	Clothing & Bedding, and Footwear
	8	Housing	Residential Building & Land, House Rent
	9	Household Effects	Furniture & Fixtures, Crockery & Utensils, Cooking & Other Household Appliances
	10	Education	Education
	11	Medical Care	Medical (Institutional), Medical (Non-institutional), Therapeutic Appliances
	12	Amusement	Entertainment, Goods for Recreation
	13	Transportation	Conveyance, Personal Transport Equipment
	14	Household Goods	Minor Durable Goods, Toilet Articles, Other Household Consumables, Other Personal Goods, Jewellery & Ornaments
	15	Household Services	Consumer Services, Taxes
Energy Items	16	Coal, Coke, Gas	Coke, Coal, Charcoal, *Gobar* Gas
	17	Firewood and Dung Cake	Firewood and Dung Cake
	18	Kerosene	Kerosene
	19	Electricity	Electricity
	20	LPG	LPG
	21	Other Petroleum Products	Candle, Petrol, Diesel, Other Fuels, Lubricants

Table 6A – Consumption Patterns (monthly per capita) in MJ of Energy Item Groups in 1993-94 and 2011-12 and its Change (%)										
		Cluster A	**Cluster B**			**Cluster C**			**Cluster D**	
		Rural	**Rural**	**Town**	**City**	**Rural**	**Town**	**City**	**Town**	**City**
		LIC	**MIC**	**LIC**	**LIC**	**HIC**	**MIC**	**MIC**	**HIC**	**HIC**
Coal, Coke, Gas	**2011-12**	22.904	28.712	21.234	14.063	26.684	10.391	4.169	2.604	0.887
	1993-94	3.628	7.093	23.227	9.818	12.918	33.203	10.960	23.336	5.532
	Increase (%)	**531%**	**305%**	**-9%**	**43%**	**107%**	**-69%**	**-62%**	**-89%**	**-84%**
Firewood and Dung Cake	**2011-12**	305.067	371.551	182.332	94.185	374.509	91.404	29.792	29.141	4.250
	1993-94	229.763	299.443	167.104	73.478	405.349	129.970	29.889	59.424	7.496
	Increase (%)	**33%**	**24%**	**9%**	**28%**	**-8%**	**-30%**	**0%**	**-51%**	**-43%**
Kerosene	**2011-12**	21.368	24.901	19.351	12.432	22.507	17.611	23.480	12.580	12.363
	1993-94	16.525	23.968	30.751	66.497	36.497	51.371	88.846	51.230	48.260
	Increase (%)	**29%**	**4%**	**-37%**	**-81%**	**-38%**	**-66%**	**-74%**	**-75%**	**-74%**
Electricity	**2011-12**	41.518	106.110	120.154	104.602	255.133	295.093	303.002	752.997	808.121
	1993-94	1.968	6.372	9.137	12.725	19.879	27.648	36.351	64.391	95.788
	Increase (%)	**2009%**	**1565%**	**1215%**	**722%**	**1183%**	**967%**	**734%**	**1069%**	**744%**
LPG	**2011-12**	0.768	10.306	26.125	27.092	51.730	77.522	73.243	119.756	101.994
	1993-94	0.037	0.597	2.907	6.805	8.950	31.260	43.051	94.725	119.405
	Increase (%)	**1996%**	**1628%**	**799%**	**298%**	**478%**	**148%**	**70%**	**26%**	**-15%**
Other Petroleum Products	**2011-12**	7.269	23.502	9.991	1.492	125.557	71.362	49.892	378.250	310.778
	1993-94	1.236	1.920	1.095	1.618	8.753	5.906	8.183	41.855	63.432
	Increase (%)	**488%**	**1124%**	**813%**	**-8%**	**1334%**	**1108%**	**510%**	**804%**	**390%**
Source: Author's calculation										